DESIGN , TESTING AND ASSEMBLY OF RECTANGULAR PATCH ANTENNA

A THESIS SUBMITTED IN PARTIAL FULFILLMENT

OF THE REQUIREMENTS FOR THE DEGREE OF

Master of Technology

in

Electrical Engineering

By

D.RAMAKRISHNA

Department of Electrical Engineering

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CERTIFICATE

This is to certify that the thesis entitled, "**DESIGN , TESTING AND ASSEMBLY OF RECTANGULAR PATCH ANTENNA**" submitted by Sri/Ms **DOMMATI RAMAKRISHNA** in partial fulfillment of the requirements for the award of MASTER of Technology Degree in **ELECTRICAL** Engineering with specialization in "**ELECTRONIC SYSTEMS AND COMMUNICATION**" at the National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by him under my our supervision and guidance.

To the best of my/our knowledge, the matter embodied in the thesis has not been submitted to any other University/ Institute for the award of any degree or diploma.

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Place:

Date: (**D Ramakrishna**)

CONTENTS

ABSTRACT

One of humankind's greatest natural resources is the electromagnetic spectrum and the antenna has been instrumental in harnessing this resource. The aim of the thesis is to Design and fabricate a coaxial fed rectangular Microstrip Antenna and study the effect of antenna dimensions Length (L) , Width (W) and substrate parameters relative Dielectric constant (ε_r) , substrate thickness on Radiation parameters of Band width and Beam width. A Microstrip antenna consists of conducting patch on a ground plane separated by dielectric substrate. Low dielectric constant substrates are generally preferred for maximum radiation. The conducting patch can take any shape but rectangular and circular configurations are the most commonly used configuration. Other configurations are complex to analyze and require heavy numerical computations. A Microstrip antenna is characterized by its Length, Width, Input impedance, and Gain and radiation patterns. The length of the antenna is nearly half wavelength in the dielectric; it is a very critical parameter, which governs the resonant frequency of the antenna. In view of design, selection of the patch width and length are the major parameters. The dielectric constant (permittivity) plays a major role in the overall performance of a patch antenna. It affects both the width, in turn the characteristic impedance and the length resulting in an altered resonant frequency. The Bandwidth of the patch antenna depends largely on the permittivity (ε_r) and thickness of the dielectric substrate. Ideally, a thick dielectric, lower permittivity (ε_r), low insertion loss is preferred for broadband purposes.

Desired Patch antenna design is initially simulated by using IE3D simulator. And Patch antenna is realized as per design requirements. From the result I observed that the experimental antenna parameters are coinciding with simulated results. Beam width of a Microstrip element can be increased by choosing a smaller element, thus reducing W and L. For given resonant frequency, these dimensions may be changed by selecting a substrate having a higher relative permittivity.

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Chapter 1

INTRODUCTION

Aim and Objectives

Overview of Microstrip Antennae

Waves on Microstrips

Antenna Characteristics

Organization of the thesis

INTRODUCTION

Communication between humans was first by sound through voice. With the desire for slightly more distance communication came, devices such as drums, then, visual methods such as signal flags and smoke signals were used. These optical communication devices, of course, utilized the light portion of the electromagnetic spectrum. It has been only very recent in human history that the electromagnetic spectrum, outside the visible region, has been employed for communication, through the use of radio. One of humankind's greatest natural resources is the electromagnetic spectrum and the antenna has been instrumental in harnessing this resource.

1.1 AIM AND OBJECTIVES

Microstrip patch antenna used to send onboard parameters of article to the ground while flight. The aim of the thesis is to Design and fabricate a coaxial fed rectangular Microstrip Antenna and study the effect of antenna dimensions Length (L) , Width (W) and substrate parameters relative Dielectric constant (ε_r) , substrate thickness on Radiation parameters of Band width and Beam width.

1.2 OVERVIEW OF MICROSTRIP ANTENNAE

A microstrip antenna consists of conducting patch on a ground plane separated by dielectric substrate. This concept was undeveloped until the revolution in electronic circuit miniaturization and large-scale integration in 1970. After that many authors have described the radiation from the ground plane by a dielectric substrate for different configurations. The early work of Munson on micro strip antennas for use as a low profile flush mounted antennas on rockets and missiles showed that this was a practical concept for use in many antenna system problems. Various mathematical models were developed for this antenna and its applications were extended to many other fields. The number of papers, articles published in the journals for the last ten years, on these antennas shows the importance gained by them. The micro strip antennas are the present day antenna designer's choice.

Low dielectric constant substrates are generally preferred for maximum radiation. The conducting patch can take any shape but rectangular and circular configurations are the most commonly used configuration. Other configurations are complex to analyze and require heavy numerical computations.

A microstrip antenna is characterized by its Length, Width, Input impedance, and Gain and radiation patterns. Various parameters of the microstrip antenna and its design considerations were discussed in the subsequent chapters. The length of the antenna is nearly half wavelength in the dielectric; it is a very critical parameter, which governs the resonant frequency of the antenna. There are no hard and fast rules to find the width of the patch.

1.3 WAVES ON MICROSTRIPS

The mechanisms of transmission and radiation in a microstrip can be understood by considering a point current source (Hertz dipole) located on top of the grounded dielectric substrate (fig. 1.1) This source radiates electromagnetic waves. Depending on the direction toward which waves are transmitted, they fall within three distinct categories, each of which exhibits different behaviors.

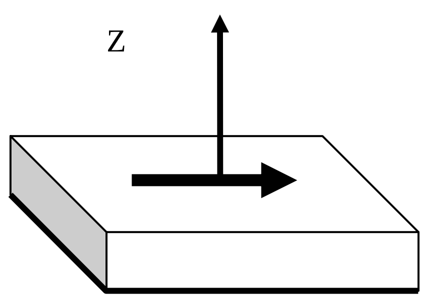


Figure 1.1 Hertz dipole on a microstrip substrate

1.3.1 Surface Waves

The waves transmitted slightly downward, having elevation angles θ between π/2 and π - arcsin ($1/\sqrt{\varepsilon_r}$), meet the ground plane, which reflects them, and then meet the dielectric-to-air boundary, which also reflects them (total reflection condition). Field amplitudes build up for some particular incidence angles, leading to the excitation of a discrete set of surface wave modes, similar to the modes in metallic wave-guide.

The fields remain mostly trapped within the dielectric, decaying exponentially above the interface (fig1.2). The vectorα, pointing upward, indicates the direction of largest attenuation. The wave propagates horizontally alongβ, with little absorption in good quality dielectric. With two directions of α and β orthogonal to each other, the wave is a nonuniform plane wave. Surface waves spread out in cylindrical fashion around the excitation point, with field amplitudes decreasing with distance (r), say$1/\sqrt{r}$, more slowly than space waves. The same guiding mechanism provides propagation within optical fibers.

Surface waves take up some part of the signal's energy, which does not reach the intended user. The signal's amplitude is thus reduced, contributing to an apparent attenuation or a decrease in antenna efficiency. Additionally, surface waves also introduce spurious coupling between different circuit or antenna elements. This effect severely degrades the performance of microstrip filters because the parasitic interaction reduces the isolation in the stop bands.

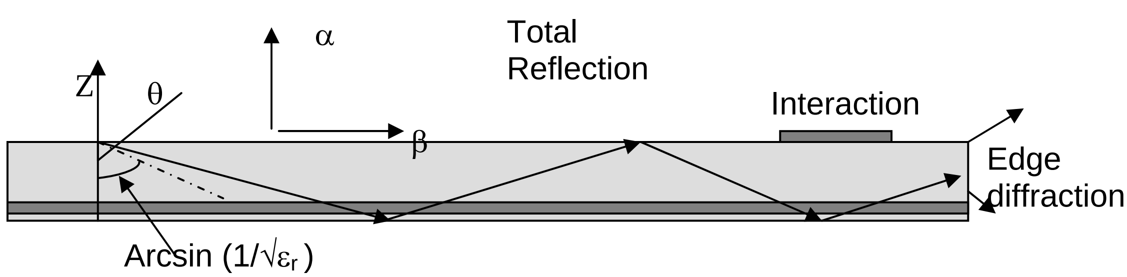


Figure 1.2.Surface waves

In large periodic phased arrays, the effect of surface wave coupling becomes particularly obnoxious, and the array can neither transmit nor receive when it is pointed at some particular directions (blind spots). This is due to a resonance phenomenon, when the surface waves excite in synchronism the Floquet modes of the periodic structure.

Surface waves reaching the outer boundaries of an open microstrip structure are reflected and diffracted by the edges. The diffracted waves provide an additional contribution to radiation, degrading the antenna pattern by raising the side lobe and the cross polarization levels. Surface wave effects are mostly negative, for circuits and for antennas, so their excitation should be suppressed if possible.

1.3.2 **Leaky Waves**

Waves directed more sharply downward, with θ angles between $\pi - \arcsin\left(1/\sqrt{\varepsilon_r}\right)$ and π, are also reflected by the ground plane but only partially by the dielectric-to-air boundary. They progressively leak from the substrate into the air (Fig 1.3), hence their name laky waves, and eventually contribute to radiation. The leaky waves are also nonuniform plane waves for which the attenuation direction α points downward, which may appear to be rather odd; the amplitude of the waves increases as one moves away from the dielectric surface. This apparent paradox is easily understood by looking at the figure 1.3; actually, the field amplitude increases as one move away form the substrate because the wave radiates from a point where the signal amplitude is larger. Since the structure is finite, this apparent divergent behavior can only exist locally, and the wave vanishes abruptly as one crosses the trajectory of the first ray in the figure.

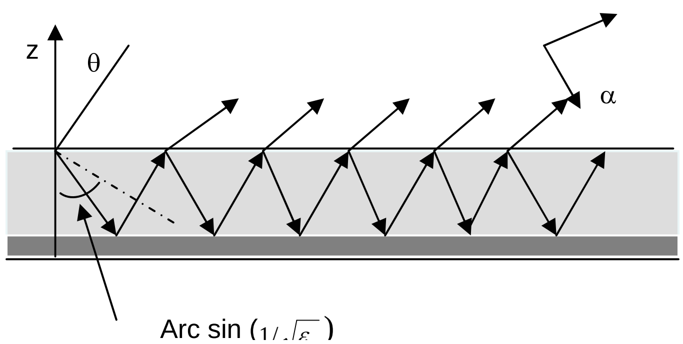


Figure 1.3 Leaky waves

In more complex structures made with several layers of different dielectrics, leaky waves can be used to increase the apparent antenna size and thus provide a larger gain. This occurs for favorable stacking arrangements and at a particular frequency. Conversely, leaky waves are not excited in some other multilayer structures.

1.3.3 **Guided Waves**

When realizing printed circuits, one locally adds a metal layer on top of the substrate, which modifies the geometry, introducing an additional reflecting boundary. Waves directed into the dielectric located under the upper conductor bounce back and fourth on the metal boundaries, which form a parallel plate waveguide . The waves in the metallic guide can only exist for some Particular values of the angle of incidence, forming a discrete set of waveguide modes.

The guided waves provide the normal operation of all transmission lines and circuits, in which the electromagnetic fields are mostly concentrated in the volume below the upper conductor. On the other hand, this buildup of electromagnetic energy is not favorable for patch antennas, which behave like resonators with a limited frequency bandwidth.

1.4 ANTENNA CHARACTERISTICS

An antenna is a device that is made to efficiently radiate and receive radiated electromagnetic waves. There are several important antenna characteristics that should be considered when choosing an antenna for your application as follows:

- Antenna radiation patterns
- Power Gain
- Directivity
- Polarization

1.5 ORGANIZATION OF THE THESIS

An introduction to microstrip antennas was given in Chapter II.The theory of radiation, various parameters and design aspects were discussed. Finally the application scenario and advantages and disadvantages were listed.

In Chapter III I deal with the choice of Substrates and analytical models. Brief introduction to various analytical models of the microstrip antenna was given. All possible substrates for the design of microsrtrp antenna with their dielectric constant and permittivity are given.

In Chapter IV I deal with various types of configurations and excitations of the antenna are described. We also mentioned various microwave connectors for feeding of signal to antenna.

Chapter V provides the design and development of microstrip antenna. A rectangular patch on FRP is designed and evaluated. The results obtained were in good agreement with the theoretical results.

Chapter VI provides information about IE3d Software for simulation of Microstrip Antennas, which will be useful for cross verification of results for designed antennas. Chapter VII gives Conclusion to this work and suggests future scope of work.

Chapter 2

MICROSTRIP ANTENNAS

Introduction

Radiation Mechanism

Important Design Parameters

Antenna Measurements

Advantages and Disadvantages

Applications

MICROSTRIP ANTENNAS

2.1 INTRODUCTION

A micro strip antenna in its simplest configuration consists of a metallic radiating patch on one side of the dielectric substrate and copper ground plane on the other side as shown in Figure 2.1.

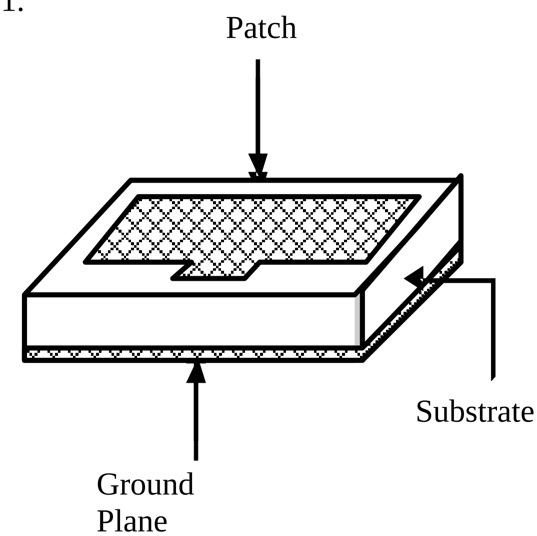


Figure 2.1 Rectangular Microstrip Antenna

Micro strip antennas are attractive due to their light weight, conformality and low cost. These antennas can be integrated with printed strip-line feed networks and active devices. This is a relatively new area of antenna engineering. The radiation properties of micro strip structures have been known since the mid 1950's.

The application of this type of antennas started in early 1970's when conformal antennas were required for missiles. Rectangular and circular micro strip resonant patches have been used extensively in a variety of array configurations.

A major contributing factor for recent advances of micro strip antennas is the current revolution in electronic circuit miniaturization brought about by developments in large scale integration. As conventional antennas are often bulky and costly part of an electronic system, micro strip antennas based on photolithographic technology are seen as an engineering breakthrough.

2.2 RADIATION MECHANISM

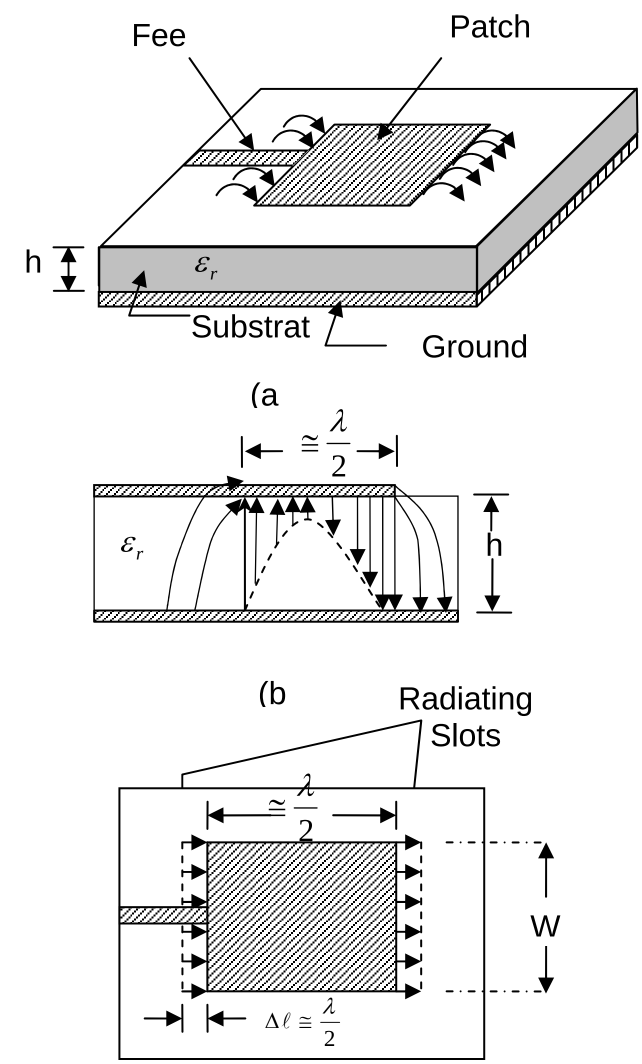
A micro strip antenna in its simplest configurations consists of a radiating patch on one side of the dielectric substrate and a ground plane on the other side. The patch conductor, normally of copper or gold, can be of any shape like rectangle, circle, triangle etc. This work considers rectangular and circular patches only. Radiation from a patch antenna depends upon the substrate parameters such as dielectric thickness, relative dielectric constant and loss tangent etc.

Radiation Phenomenon:

Radiation from micro strip antenna (MSA) can be understood by considering the simplest case of rectangular micro strip patch spaced a small fraction of wave length above a ground plane as shown in figure 2.2a.Assuming no variations of electric field along the width and the thickness of the micro strip structure, the electric field configuration of the radiator can be represented as shown in figure 2.2b. Radiation can be ascribed mostly to fringing fields at the open circuited edges of the patch.

The fields at the end can be resolved into normal and tangential components with respect to the ground plane. The normal components are out of phase because the patch length is $\lambda/2$ long, therefore the far fields produced by them in the broadside direction. The tangential components (those parallel to the ground plane) are in phase, and the resulting fields combine to give maximum radiated field normal to the surface of the structure, i.e., the broadside direction.

Therefore, the patch may be represented by two slots $\lambda/2$ apart as shown in figure 2.2c excited in-phase and radiating in the half space above the ground plane. One may also consider the variation of fields along the width of the patch. In this case, the mirostrip patch antenna may be represented by four slots surrounding the patch structure.



(c)

Figure: 2.2 *(a) Rectangular Micro strip Antenna*

(b) Side view and

(c) Top view

2.3 IMPORTANT DESIGN PARAMETERS

(1) Input impedance: The input impedance or admittance of a micro strip radiator is an essential parameter and it should be accurately known so as to provide a good match between the element and the feed.

(2) Q-factor and Losses: The Q-factor of the antenna is primarily affected by the substrate thickness, dielectric constant and loss tangent. The main losses are through radiation, surface wave generation, dielectric losses and conductor losses. The associated Q-factors are: Q_r, Q_s, Q_d and Q_c respectively. The overall Q is given by

$$\frac{1}{Q_T} = \frac{1}{Q_r} + \frac{1}{Q_s} + \frac{1}{Q_d} + \frac{1}{Q_c} \qquad (2.1)$$

For optimal bandwidth the over all Q (i.e., Q_T) must be minimized i.e., the losses should remain small.

(3) Bandwidth: The bandwidth (B) of a micro strip antenna for a feed line VSWR < S can be shown to be

$$BW = \frac{S-1}{Q_T\sqrt{S}} \qquad (2.2)$$

Where Q_T is the total quality factor. A typical plot of BW for a micro strip element of VSWR < 2 is shown in Fig 2.3. For a given frequency, larger bandwidth is possible by choosing a thicker substrate. The curves also indicate that a lower of ε_r also results in a larger bandwidth.

2.4 ANTENNA MEASUREMENTS:

Once an antenna is designed and fabricated, it needs to be evaluated for its electrical performance. The following are some parameters to be measured:

(i) Input Impedance

(ii) Radiation pattern for Beam width

(iii) Gain

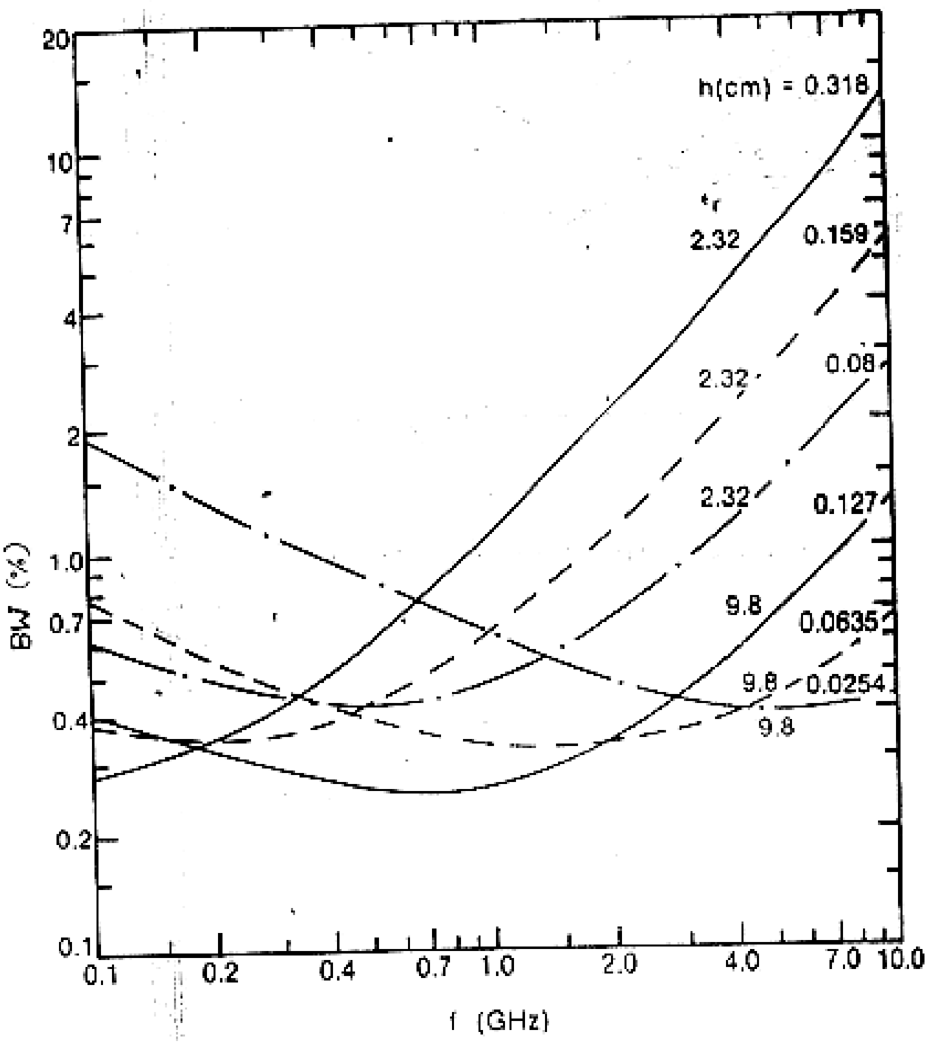


Fig 2.3: Variation of Bandwidth with frequency for different Dielectric substrate Antennas

2.4.1 Input Impedance

The input impedance or admittance for a microstrip radiator is an essential parameter; it should be accurately known so as to provide good match between the element and the feed. The input admittance at any arbitrary feed point as shown in figure 2.4 can be obtained by transforming the slot admittances to that point. This can be done with the help of the following equation:

$$Y_{in}(z) = 2G\left[\cos^2(\beta z) + \frac{G^2 + B^2}{Y_o^2}\sin^2(\beta z) - \frac{B}{Y_o}\sin(2\beta z)\right]^{-1}$$

Where Z = distance of the feed point from the corner.

β = Phase constant.

G = Conductance

Yin = Input Admittance

Using a program written in Matlab, the input admittance Yin at every point along the width is calculated to match the 50Ω co-axial cable to the element. The point Z where Yin=50Ω is the location of the feed. If the feed point is moved across the Width of the resonator, a large range of input impedance values as shown in figure 2.4 may be obtained, so the element may be matched to all practical impedance levels.

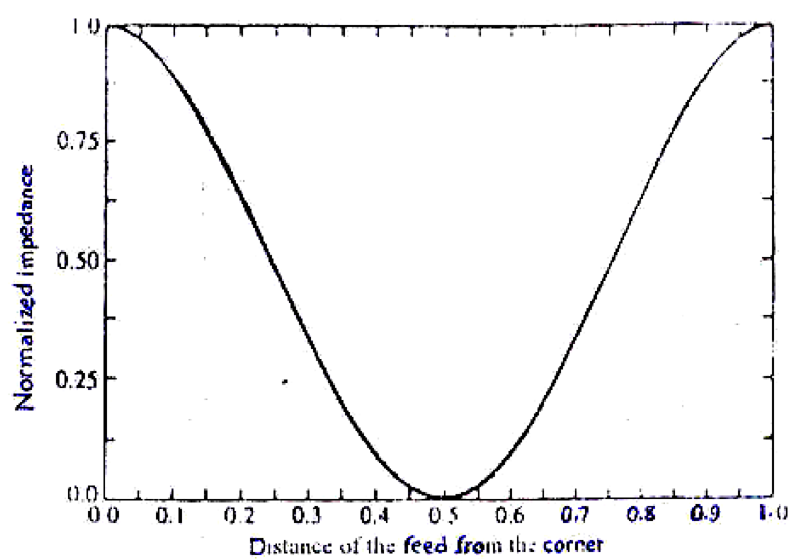


Figure 2.4 Impedance variations with feed location

2.4.2 Radiation Pattern

The radiation pattern of an antenna is usually represented graphically by plotting the electric field of the antenna as a function of direction. This electric field strength is expressed as 'E' volts per meter or normalized field in dB.

A complete radiation pattern comprises the radiation for all angles of ϕ and θ and really requires three- dimensional presentation. This is quite complicated. For practical purposes, the pattern is measured in planes of interest. Cross sections in which the radiation patterns are most frequently taken are the horizontal (θ = 90o) and vertical (ϕ = constant) planes. These are called the horizontal pattern and vertical patterns, respectively. The terms commonly used are the E-plane and H-plane, and they are the planes passing through the antenna in the direction of beam maximum and parallel to the far-field E and H vectors. These two patterns are known as the 'principal plane' patterns.
The radiation patterns of the antennas are measured with the Scientific Atlanta instrumentation in an anechoic chamber. The instrumentation consists of four major parts as shown in Figure 2.5 they are.

(a) Transmitting system
(b) Positioning and control system
(c) Receiving system
(d) Recording system

(a) Transmitting subsystem: The transmitting or source instrumentation consists primarily of the RF signal source and associated transmitting antenna.

Signal source: The Model 2150 signal source provides RF power in the 0.1 to 18 GHz frequency range. The control unit is located near the operator's console. The RF oscillators are installed in the mainframe assembly which is mounted near the source antenna.

Source antenna: Several types of antennas designed especially for the antenna test range can be used. These include standard gain horns, dipoles, parabolic reflector antennas, log periodic arrays and circularly polarized antennas depending upon the requirement.

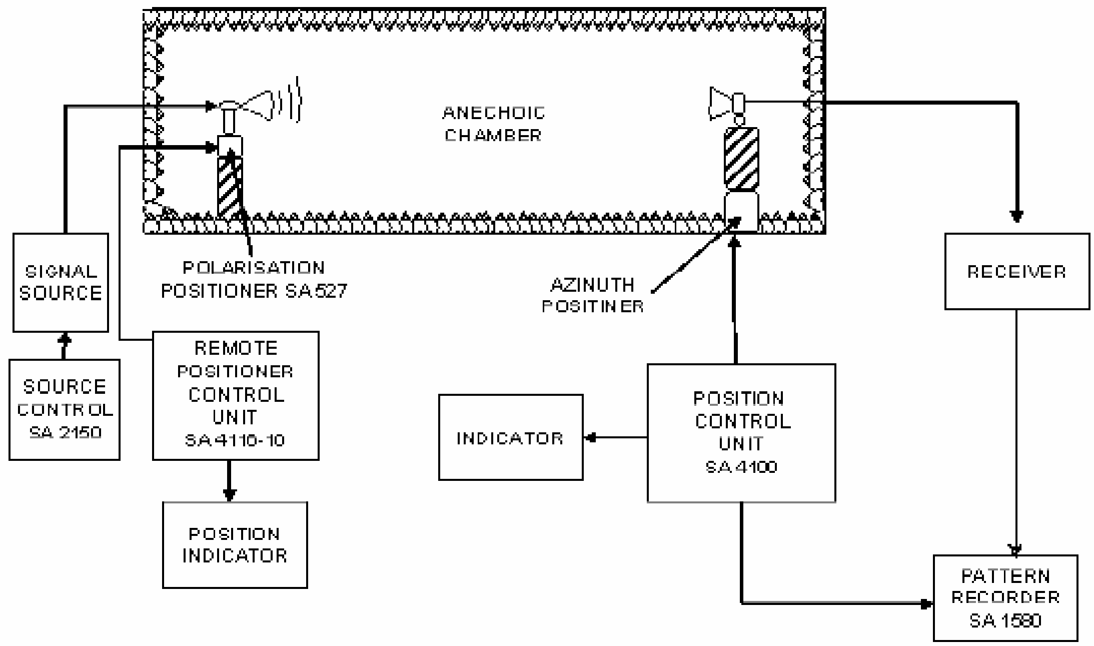


Figure (2.5) . Experimental setup for plotting Radiation Pattern.

(b) Positioning and control systems: The antenna to be tested is mounted on the turn table of the antenna test positioner. The speed and direction of the rotation of the test antenna can be controlled from the operator's console by a direct current motor.

A synchro transmitter is mechanically coupled to the postitioner turntable and electrically to a position indicator.

The antenna test positioner is controlled by the series 4100 positioner control unit. Electrical cables are used to supply power from the control system to the test positoner.

Indicator system: A position indicator allows remote angle readout of the test positioner. The synchro transmitter in the test positioner provides the position data to operate the position indicator.

(c) Receiving system: The antenna under test usually tested in the receive mode. Therefore, a receiving or detecting system must be connected to the test antenna to convert the RF signal to a low frequency (audio) signal which can drive the pen system of the pattern reorder. Thus the antenna must receive an RF signal that is modulated with an audio signal. The Model 2150 signal source has an audio oscillator as a standard feature.

The two types of detectors commonly used for making antenna measurements are the crystal detectors and Bolometer. Scientific Atlanta antenna pattern recorders will operate crystal detectors or bolometer detectors directly.

(d) Antenna Pattern Recorder: The radiation patterns of an antenna are recorded as relative amplitude and / or phase as a function of position (or angle). The synchro position data from the test positioner is connected to the recorder's chart servo system. The resultant graph is a plot of relative amplitude of the received signal as a function of the antenna position (or angle).

2.4.3 GAIN

The setup used for measurement of gain is the same as that used for pattern measurement given in Figure (2.5). The gain of the antenna is measured by replacing the test antenna with a standard antenna and taking the patterns of the same. The gain is then calculated by comparing the power level differences of the test antenna with that of the standard antenna.

2.4.4 RETURN LOSS OR VSWR:

The Return loss is the measure of power reflected and is related to the reflection coefficient 'Γ'by

Return loss in dB = $20\log|\Gamma|$

The relation between reflection coefficient and VSWR is given by:

$$VSWR(S) = \frac{1+|\Gamma|}{1-|\Gamma|}$$

The experimental setup used for measuring return loss of the antenna is shown in Figure (2.6) Experimental setup for Measuring Return Loss

The experimental setup consists of:

(a) Sweep Oscillator

(b) Dual Directional Coupler

(c) Network Analyzer

(a) Sweep Oscillator: The power is fed to the antenna, from the sweep oscillator through the dual directional coupler as shown in Figure (2.6). The sweep oscillator used was 8350B, whose sweep sizes can be fixed so that the power will be fed to the antenna between the required ranges of frequencies from start to stop.

(b) Dual Directional Coupler: The dual directional coupler consists of 4 ports, an input port at which the power is incident from the sweep oscillator and a test port at which the antenna whose return loss is to be measured is connected. In the dual directional coupler a part of the incident input power is coupled to a coupled port; similarly, the reflected power from the antenna is coupled to isolated port. The ratio of isolated power to coupled power will give us the reflection coefficient ‘Γ’.

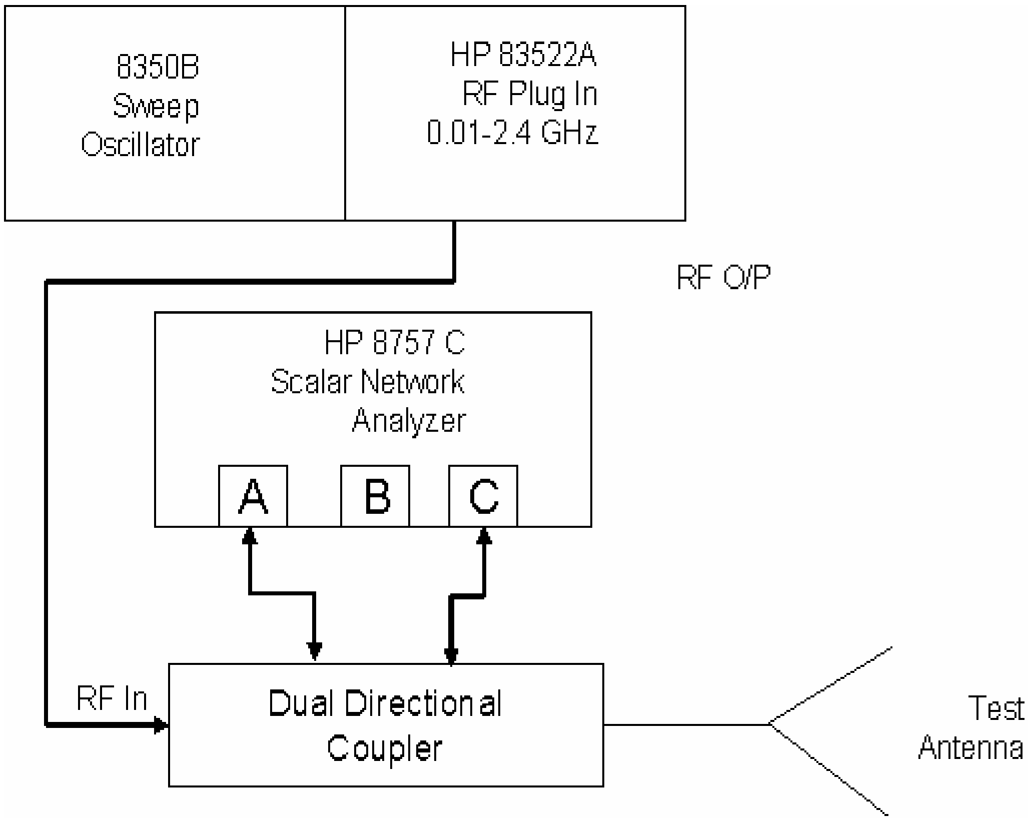


Figure 2.6 Experimental setup for Measuring Return Loss

c) Network Analyzer: The reflection coefficient 'Γ' is fed to the network analyzer which converts this to dB to get the return loss. Then the values of return loss at different frequencies in the sweep range fixed will be displayed on the screen of the network analyzer. A HP 8757C Scalar Network Analyzer and HP 8510B Vector Network Analyzer were employed in the present measurements.

Before measuring the return loss of the antenna the network analyzer should be calibrated as explained below:

(i) The terminal at the test port at which the test antenna is to be mounted is short circuited. Now the power fed to the test port travels back through the short circuits so that there will be no radiation at all. The reflected power will be equal to the incident power and so the reflection coefficient is equal to 1, which in turn leads to a return loss of zero dB, therefore, when the test port terminals are short circuited, we must get a zero dB line on the display.

(ii) The terminals at the test port are now open circuited. The power fed to the test port can not be radiated because there is no load. So all the power reflects back. The reflection coefficient is 1 and therefore leads to a return loss of zero dB. Hence when the terminals at the test port are open circuited the screen should display a 0 dB line.

During short circuit of test port terminals the power reflects back with phase reversal. During the open circuit, the reflected power is in-phase with respect to the incident power.

These two settings are stored in memory and the setup is ready for practical measurements. The antenna is then connected at the test port and the observed plot is the return loss of the antenna. The percentage bandwidth at -10dB return loss is:

$$\% \text{ Bandwidth} = \frac{f_2 - f_1}{f_r} \times 100$$

Where (f2 – f1) is the frequency band for which the return loss is less than 10 dB.

The measurement setup explained above has been used to evaluate the micro strip antennas designed and explained in Chapter V.

2.5 ADVATEGES AND DISADVANTAGES

Micro strip antennas have many advantages over conventional antennas. Some important advantages are:

(1) Light weight, low volume, low profile configurations used for space applications where weight is a major constraint.

(2) Micro strip antennas can be fabricated conformal to the surface of missiles, Spacecrafts etc, which does not disturb the aerodynamics of the aerospace vehicles.

(3) Low fabrication cost and readily amenable for mass production. This the most attractive feature for array applications.

(4) Micro strip antennas are compatible with modular designs. Solid state devices such as oscillators, amplifiers etc, can be fabricated directly to the antenna substrate board.

(5) Feed lines and matching network can be fabricated simultaneously with the antenna structure.

The main drawbacks of micro strip antennas are:

(1) The bandwidth of micro strip antennas is usually 1% to 3%. This is a major drawback which restricts the number of applications, but specific applications are met.

(2) Losses in micro strip antenna are high

(3) Micro strip antennas radiate into half space.

(4) They have low power handling capability.

(5) They have poor end fire radiation performance

Some of the disadvantages given above can be overcome to some extent depending upon the type of application.

2.6 APPLICATIONS

The disadvantages of micro strip antennas outweigh the advantages in many applications. Some notable fields where micro strip antennas are exclusively used are:

(1) Satellite and mobile communications,

(2) Doppler and other radars,

(3) Radio altimeter,

(4) Command and control,

(5) Feed elements in complex antennas.

Chapter 3

ANALYSIS OF A RECTANGULAR PATCH RADIATOR

ANALYSIS OF A RECTANGULAR PATCH RADIATOR

3.1 INTRODUCTION

The simplest configuration of micro strip antenna (MSA) is a rectangular strip conductor on a thin dielectric substrate backed by a ground plane. The simplicity of the structure has led to numerous attempts to predict and evaluate the radiation characteristics of rectangular MSA. A rectangular patch radiator may be completely characterized in terms of its radiated field pattern, input impedance, gain bandwidth, beam width, efficiency, losses and Q-factor, Although the methods of analyses may vary, ultimately the optimum method in terms of design cost and performance predication is one which can be predicated using simple expressions, and agrees well with experimentally obtained results. The mathematical analysis of the micro strip patch can be undertaken at several levels of sophistication, with choice of the method dependant on the need for the design accuracy as well as the shape of the patch.

3.2 ANALYTICAL MODELS

There are many methods of analysis for the micro strip antennas. They can be broadly classified into two categories-

1. Model-based analysis techniques
2. Full-wave analysis techniques

The various model-based and Full-wave analysis techniques that have been used for the analysis of Rectangular micro strip antennas are:

- Wire Grid Model
- Cavity Model
- Modal Expansion Model
- Transmission line Model
- Integral equation method
- Vector Potential approach

The Transmission line model considers the antenna as two radiating slots perpendicular to the feed line of length ‘L’. This model is easy to use and analyze due to its simplicity but suffers from some disadvantages. This model is limited to square and rectangular geometries. It gives less physical insight and ignores field variations along the radiating edge. It is not adequate for predicting impedance variation with feed location over the surface of the patch.

Transmission model is adapted in this work for analysis of rectangular and square micro strip antennas. More details are presented in the following section.

3.3 ANALYSIS OF MICRO STRIP ANTENNA USING TRANSMISSION LINE MODEL

All the models mentioned above, except the transmission line model, are partially successful in predicting the performance of the micro strip radiator and require considerable calculations. The Transmission line model leads to results adequate for most engineering purposes and requires less computation. This model has been validated with a large amount of experimental data with good results for resonant frequency and input impedance for elements on thin, low dielectric constant substrates.

The micro strip radiator element may be treated as a line resonator with no transverse field variations. The fields vary along the length, which is usually a half-wave length, and radiations occur mainly from the fringing fields at the open circuited ends. The radiator may be represented as two slots spaced a distance L apart in the x-y plane as shown in figure 3.1.

Each slot radiates the same field as a magnetic dipole with magnetic current of:

$$\overline{M} = \hat{z}\, 2E_x = \hat{z}\, 2V_o / h, \qquad (3.1)$$

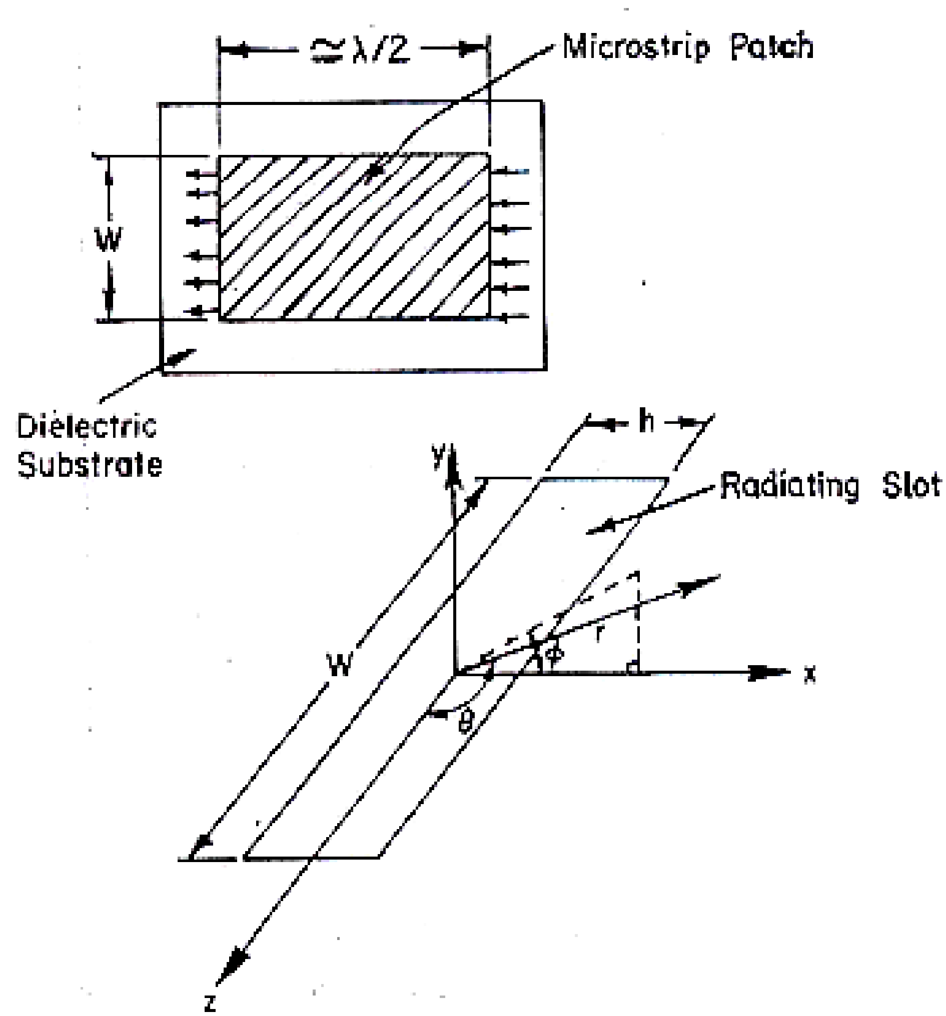


Figure: 3.1 Micro strip Antenna Represented as two Radiating Slots with the Slot Geometry and co ordinate system.

Where the factor 2 arises due to the positive image of $\overline{M}$,which is near the ground plane, and V_o is the voltage across the slot which is invariant with x over its width.

For a single slot the far field at a distance r from the origin is:

$$E_{\phi} = -j2V_o W k_o \frac{e^{-jk_o r}}{4\pi r} F(\theta,\phi) \tag{3.2}$$

$$E_{\theta} = 0$$

Where

$$F(\theta,\phi) = \frac{\sin\left(\frac{k_o h}{2}\sin\theta\cos\phi\right)}{\frac{k_o h}{2}\sin\theta\cos\phi} \frac{\sin\left(\frac{k_o W}{2}\cos\theta\right)}{\frac{k_o W}{2}\cos\theta}\sin\theta \tag{3.3}$$

For θ = π/2, F (ϕ) the E-plane pattern can be determined from:

$$F(\phi) = \frac{\sin\left(\frac{k_o h}{2}\cos\phi\right)}{\frac{k_o h}{2}\cos\phi} \tag{3.4}$$

Similarly, for ϕ = π/2, F (θ) will represent the H-plane pattern and may be written as

$$F(\theta) = \frac{\sin\left(\frac{k_o W}{2}\cos\theta\right)}{\frac{k_o W}{2}\cos\theta}\sin\theta \tag{3.5}$$

Hence, for two slots space a distance L apart. The E-plane radiation pattern is:

$$F_T(\phi) = \frac{\sin\left(\frac{k_o h\cos\phi}{2}\right)}{\frac{k_o h}{2}\cos\phi}\cos\left(\frac{k_o L}{2}\cos\phi\right) \tag{3.6}$$

Where as the H-Plane pattern is independent of L and is given by equation (3.5).

The radiated power may be obtained by integrating the real part of the Poynting vector over the hemisphere and may be expressed for h << λo as

$$P_r = \frac{V_o^2 I_1}{240\pi^2} \tag{3.7}$$

Where $I_1 = \int_0^{\pi} \sin^2\left(\frac{k_0 W \cos\theta}{2}\right) \tan^2\theta \sin\theta d\theta.$

The radiation resistance Rr is then:

$$R_r = \frac{V_o^2}{2P_r} = \frac{120\pi^2}{I_1} \qquad (3.8)$$

For

W << λo, Rr = 90 λo2 / W2 (3.9)

W >> λo, Rr = 120 λo2 / W (3.10)

For the latter case, the radiation resistance per unit length of the slot is therefore

Rr = 120 λo Ω/m (3.11)

This is a simplification (for small h) of the complete expression [27]:

$$R_r = \frac{120\lambda_o}{1 - \frac{(k_o h)^2}{24}} \qquad (3.12)$$

Using the expression for the normalized line extension Δl from equation (5.3) the slot susceptance, represented by a capacitance may be shown to be

$$C = \frac{\Delta\ell\sqrt{\varepsilon_e}}{cZ_o} \qquad (3.13)$$

Where Zo is the characteristic impedance of the micro strip line and c is the velocity of light. Hence the input admittance of the radiating element may be expressed as:

$$Y_{in} = G + jB + Y_o \frac{G + j(B + Y_o \tan\beta L)}{Y_o + j(G + jB)\tan\beta L} \qquad (3.14)$$

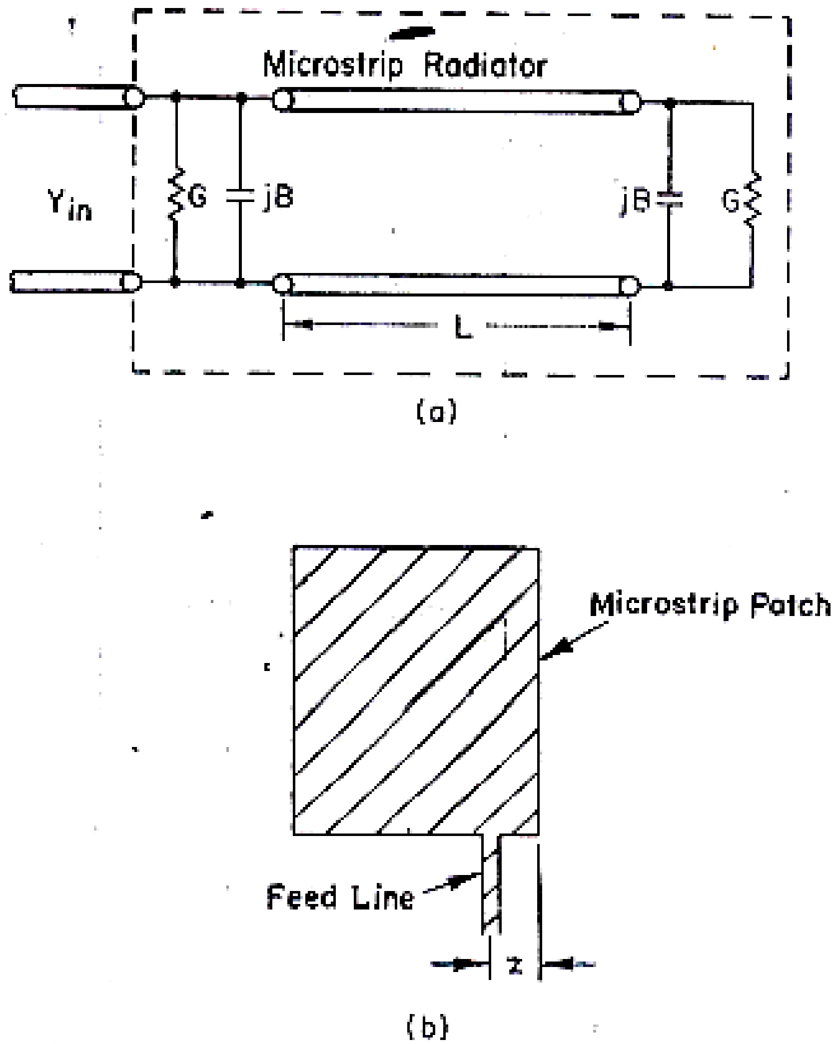


Figure 3.2 (a) The Equivalent Circuit for a Micro strip Radiating Element
(b) Micro strip patch with arbitrary Feed point

Where G = 1/ Rr, $B = \frac{k_o \Delta l \sqrt{\varepsilon_e}}{Z_o}$

β is the propagation constant = $\frac{2\pi\sqrt{\varepsilon_e}}{\lambda_o}$ and Yo = 1/Zo.

The equivalent circuit for this model is shown in fig 3.2 a. The micro strip element is represented by two admittances connected by a transmission line. Since at resonance, the imaginary part of the input admittance Yin is zero, the resonant frequency of the radiator can be calculated from

$$\tan \beta L = \frac{2Y_o B}{B^2 + G^2 - Y_o{}^2} \tag{3.15}$$

The input admittance at any arbitrary feed point as shown in fig 3.2b may be obtained by transforming the slot admittances to that point. The resulting expression is [21]:

$$Y_{in}(z) = 2G\left[\cos^2(\beta z) + \frac{G^2 + B^2}{Y_o^2}\sin^2(\beta z) - \frac{\mathbf{B}}{Y_o}\sin(2\beta z)\right]^{-1} \tag{3.16}$$

Where z is the distance of the feed point from the corner. This expression can be further simplified for the practical case of G/Yo<<1 and B/Yo<<1, to:

$$Y_{in}(z) = \frac{2G}{\cos^2(\beta z)} \tag{3.17}$$

Which is valid everywhere except for βz = π/2. Further, the mutual conductance for the interaction between the two radiating slots may be shown to be [19]

$$g_{12} = \frac{1}{120\pi^2}\int_0^{\pi} \frac{\sin^2\left(\frac{\pi W \cos\theta}{\lambda_o}\right)\tan^2\theta \sin\theta J_o\left(\frac{2\pi L}{\lambda_o}\sin\theta\right)}{G} d\theta \tag{3.18}$$

Where Jo(x) is the Bessel function of order zero and argument x. Using (3.18), the input admittance expression is modified to

$$Y_{in}(z) = 2(G \pm g_{12}) / \cos^2(\beta z) \tag{3.19}$$

If the feed point is moved across the width of the line resonator, a large range of input impedance values may be obtained, so the element may be matched to all practical impedance levels. However, this model does not take the position of the source point along the length of the resonator into consideration.

To overcome this limitation of the transmission line model, Newman and Tulyathan [19] have proposed a combination of surface-patch and transmission line modeling. Consider a micro strip antenna and its equivalent circuit as shown in fig 3.3.

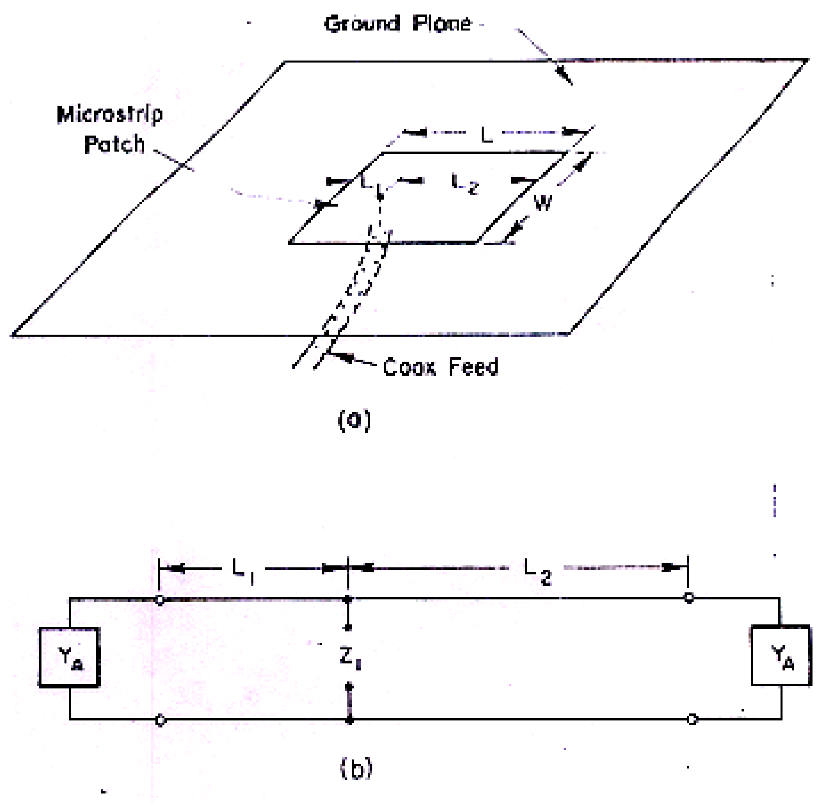


Figure 3.3: Coaxial Fed Micro strip Patch Radiator with Transmission line Equivalent

The admittance Y_w is given by Equation

$$Y_{wy} = Y_w = G_w + jB_w$$

Where

$$G_w = 0.00836 W\lambda_o$$

$$B_w = 0.01668 \frac{\Delta l}{h} \frac{W}{\lambda_o} \varepsilon_e$$

and transforming it through distances L1 and L2, the input admittance at the feed point is:

$$Y_1 = Y_o \left[\frac{Z_o \cos \beta L_1 + jZ_w \sin \beta L_1}{Z_w \cos \beta L_1 + jZ_o \sin \beta L_1} + \frac{Z_o \cos \beta L_2 + jZ_w \sin \beta L_2}{Z_w \cos \beta L_2 + jZ_o \sin \beta L_2} \right] \tag{3.20}$$

Z_w=1/Yw and Z_o is the characteristic impedance of the micro strip.

At the co-axial aperture, the probe may be represented by a lumped inductive reactance [17]

$$X_L = \frac{377}{\sqrt{\varepsilon_r}} \tan\left(\frac{2\pi h}{\lambda_o} \right) \tag{3.21}$$

And hence the input impedance is

$$Z_{in} = Z_1 + jX_L \qquad \text{(Z1 = 1/Y1)} \tag{3.22}$$

In the combined surface patch and Transmission line model, first the micro strip antenna input impedance is determined at a frequency f_a assuming an air dielectric substrate, and equation (3.16) is solved for the aperture admittance. The aperture admittance for the dielectric substrate case, near its resonant frequency f_d is then obtained using the expression:

$$G_w^d = \frac{f_d}{f_a} \sqrt{\varepsilon_e} G_w^a \tag{3.23 a}$$

$$B_w^d = \frac{\Delta\ell_d}{\Delta\ell_a}\frac{f_d}{f_a}\varepsilon_e B_w^a \tag{3.23 b}$$

Where the subscripts a and d respectively denote quantities for air and actual dielectric, and the $\Delta\ell$'s are obtained from Equation (5.3).

3.4 CHOICE OF SUBSTRATE

The first step in designing an antenna is to choose an appropriate substrate. A wide range of substrate materials is available, clad with copper, aluminum or gold. Low cladding thickness simplify fabrication of the antenna to required tolerances, whereas thicker clad ease soldering. For high power applications of micro strip antennas, a thick cladding is desirable. The range of substrates available, viz.., PTFE (Polytetra fluorothylene), Polystyrene, Polyolefin, Polyphenylene, ceramic, etc., permits considerable flexibility in the choice of a substrate for particular applications.

There is no one ideal substrate, the choice rather depends on the application. For instance, conformal microstrip antennas require flexible substrates, while low frequency applications require high dielectric constants to keep size small. Micro strip patch antennas use low dielectric substrates.

Substrate choice and elevation is an essential part of the design procedure. Many substrate properties may be involved in these considerations: dielectric constant and loss tangent and their variation with frequency and temperature, homogeneity, isotropicity, thermal coefficient and temperature range, dimensional stability with processing, temperature, humidity, aging and thickness uniformity of the substrate are all of importance. Similarly, other physical properties, such as resistance to chemicals, tensile and structural strengths, flexibility, impact resistance, strain relief, formability, bond ability and substrate characteristics when clad, are important in fabrication.

Substrate dimensions and dielectric constant are functions of substrate temperature, so the operating temperature range must be considered in the result. Applications, where this consideration is important are high-speed missiles, rockets, weaponry, other defense applications. Dielectric constant and loss tangent are also functions of frequency. Thus the properties of the substrates at one frequency cannot be expected to be equally as valid at another frequency. The substrate chosen for development of micro strip antenna in the project is Duriod since it has most amenable properties for the missile applications.

Chapter 4

MICROSTRIP ANTENNA CONFIGURATIONS AND EXCITATIONS

Introduction

Various Configurations

Feeding Methods

MICROSTRIP ANTENNA CONFIGURATIONS AND EXCITATIONS

4.1 INTRODUCTION

Micro strip antennas are characterized by more physical parameters than are conventional microwave antennas. They may be of any geometrical shape and any dimension. However, all micro strip antennas can be divided into three basic categories: micro strip patch antennas, micro strip traveling-wave antennas, and micro strip slot antennas. The plot of impedance variation with reference to variation in feed point is as shown in Figure 2.4 of Chapter-II.

When choosing the most appropriate micro strip antenna configuration for a particular application, the means of excitation of the radiating element is an essential and important factor. Hence the feed type has to be selectively chosen to obtain accurate results. The two main types of feed are the co-axial and the microstrip feed. Apart from the feed type the feed location is also one of the most critical parameters that decide the characteristics of a micro strip antenna. The impedance of the antenna is highly sensitive to even slight changes in the feed location.

4.2 VARIOUS CONFIGURATIONS

Micro strip antenna configurations are divided into three basic categories.

- Micro strip patch antennas
- Micro strip traveling-wave antennas
- Micro strip slot antennas

4.2.1 Micro Strip Patch Antennas

A micro strip patch antenna (MPA) consists of a conducting patch of any planar geometry on one side of a dielectric substrate backed by a ground plane on the other side.

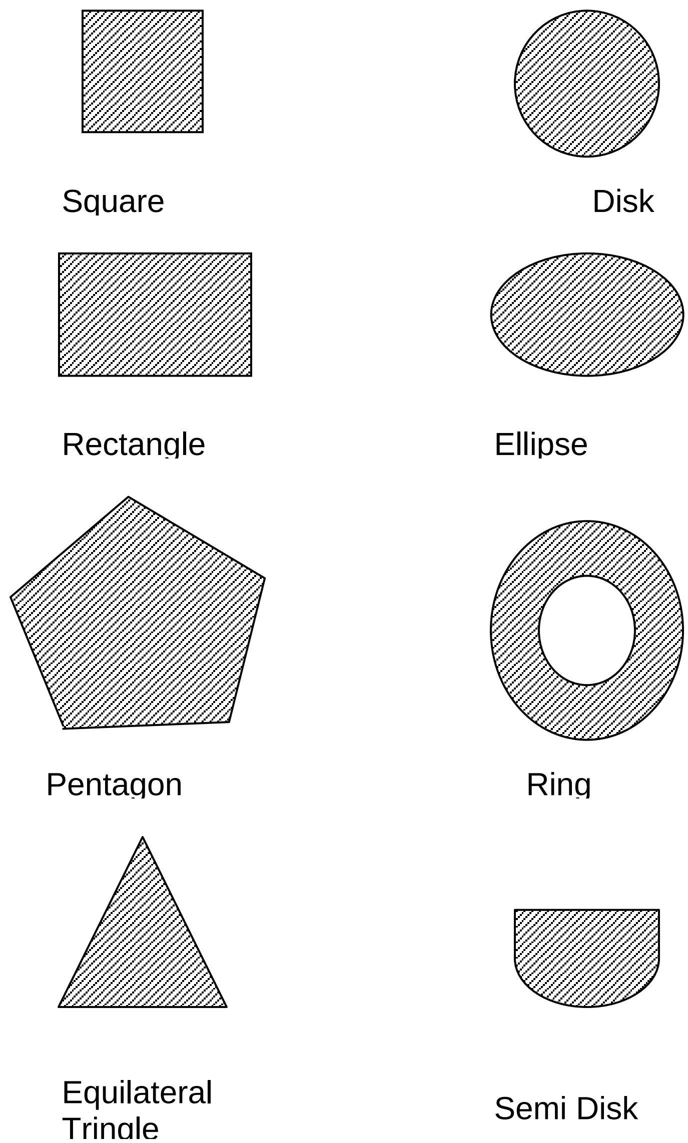


Figure 4.1 Various Micro strip Antenna Configuration Used in Practice

4.2.2 Micro Strip Traveling-Wave Antennas

Micro strip traveling-wave antennas (MTA) consist of chain-shaped periodic conductors or an ordinary long TEM line which also supports a TE mode, on a substrate backed by a ground plane. The open end of the TEM line is terminated in a matched resistive load. As antennas support traveling waves, their structures may be designed so that the main beam lies in any direction from broadside to endfire. Various configurations for MTA are shown in Figure 4.3.

4.2.3 Micro Strip Slot Antennas

Micro strip slot antennas comprise a slot in the ground plane fed by a microstrip line. The slot may have the shape of a rectangle (narrow or wide), a circle or an annulus as shown in Figure 4.4

4.3 FEEDING METHODS

Most micro strip antennas (MAs) have radiating elements on one side of a dielectric substrate, and thus may be fed by a microstrip line, co-axial probe, aperture coupling and proximity coupling. Matching is usually required between the feed line and the antenna; because antenna input impedance differ from the customary 50 ohm line impedance.

Matching may be achieved by properly selecting the location of the feed line. However, the location of feed may also affect the radiation characteristics. The Green's function technique can be used to determine the effect of feed location both for micro strip and coaxial feeds.

4.3.1 Co-Axial Feed

The coaxial method of coupling is as shown in Figure 4.5. This has the advantage that the feed lies behind the radiating surface, and therefore does not itself contribute unwanted radiation. Patch is fed by means of a surface mounted coaxial connector attached to the micro strip ground plane. The probe is positioned at a point where the input impedance of the patch, Z_{in}, is equal to characteristic impedance of the feed line.

The inductive reactance of the probe adversely affects VSWR bandwidth in this type of coupling, particularly if a thick, low permittivity substrate is used in order to increase the gain bandwidth. The VSWR bandwidth can be broadened by adding series capacitive reactance compensation as close as possible to the inductance, to provide a series circuit resonant at the same frequency as the patch .

It is a very convenient method of feeding a single patch but is not suited for array system. The disadvantage for an array system is that the feed network must lie in a separate layer behind the radiating surface, so the complete antenna cannot be etched on a single substrate. There is a consequent increase in complexity. An additional disadvantage, particularly at high frequencies, is that the necessity for inserting properly secured probes results in extra mechanical complexity and increased manufacturing costs, particularly for large arrays.

4.3.2 Micro Strip Feed

In this type of feed, the centre-fed antenna patch is etched together with the feed line, as shown in figure 4.6. Once the size of the antenna element is determined, matching procedure proceeds as follows. The centre-fed antenna patch is etched together with the 50 Ωfeed lines. The input impedance at the feed point is measured and a matching transformer is designed. The antenna is reconstructed, incorporating the matching section between the antenna element and the feed line.

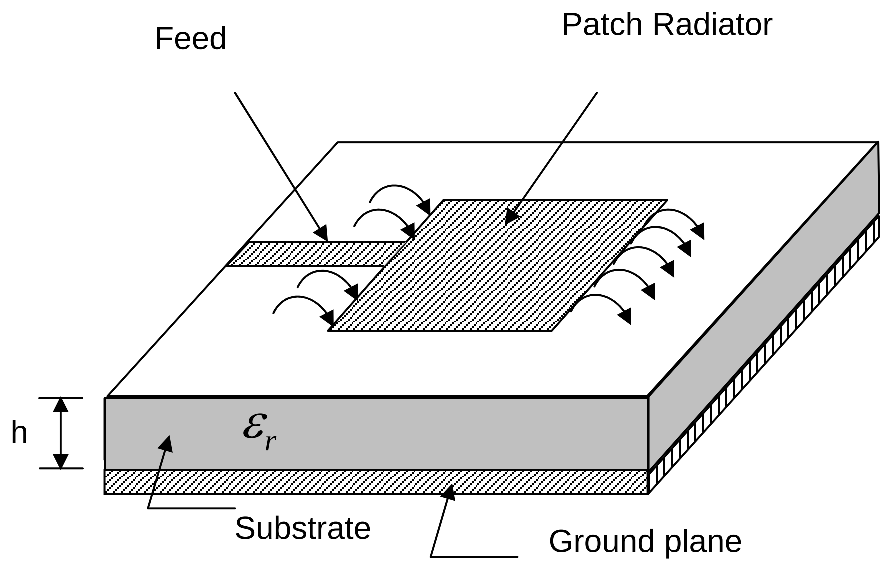


Figure 4.2 Micro strip fed Patch Antenna

Micro strip feed is of particular advantage in the case of large arrays. But when a single antenna element is considered, the coaxial type of feed is more advantageous. The main drawback of the micro strip feed is that the strip used for the feed line also radiates and interferes with the radiation coming from the patch. Another disadvantage of the micro strip feed is that a matching transformer should be designed to match the feed impedance to the antenna input impedance, which involves additional calculations and reconstruction procedure.

The type of feed used to develop the microstrip antenna in this thesis is the co-axial type of feed.

Chapter 5

DESIGN, FABRICATION AND EVOLUTION OF MICROSTRIP ANTENNAS

DESIGN, FABRICATION AND EVALUATION OF MICROSTRIP ANTENNAS

5.1 INTRODUCTION

Theory, design and analysis of microstrip antennas have been described in chapters II & III. The Practical Implementation of microstrip antenna involves the following stages:

1) Design of microstrip antennas
2) Fabrication and measurements of the antennas

5.2 DESIGN OF MICROSTRIP ANTENNAS

The configuration namely, a rectangular patch on 1.5 mm thick RT/Duriod has been designed. The details are presented in this chapter. The specifications for the design of the microstrip antenna are given in Appendix-ii ..

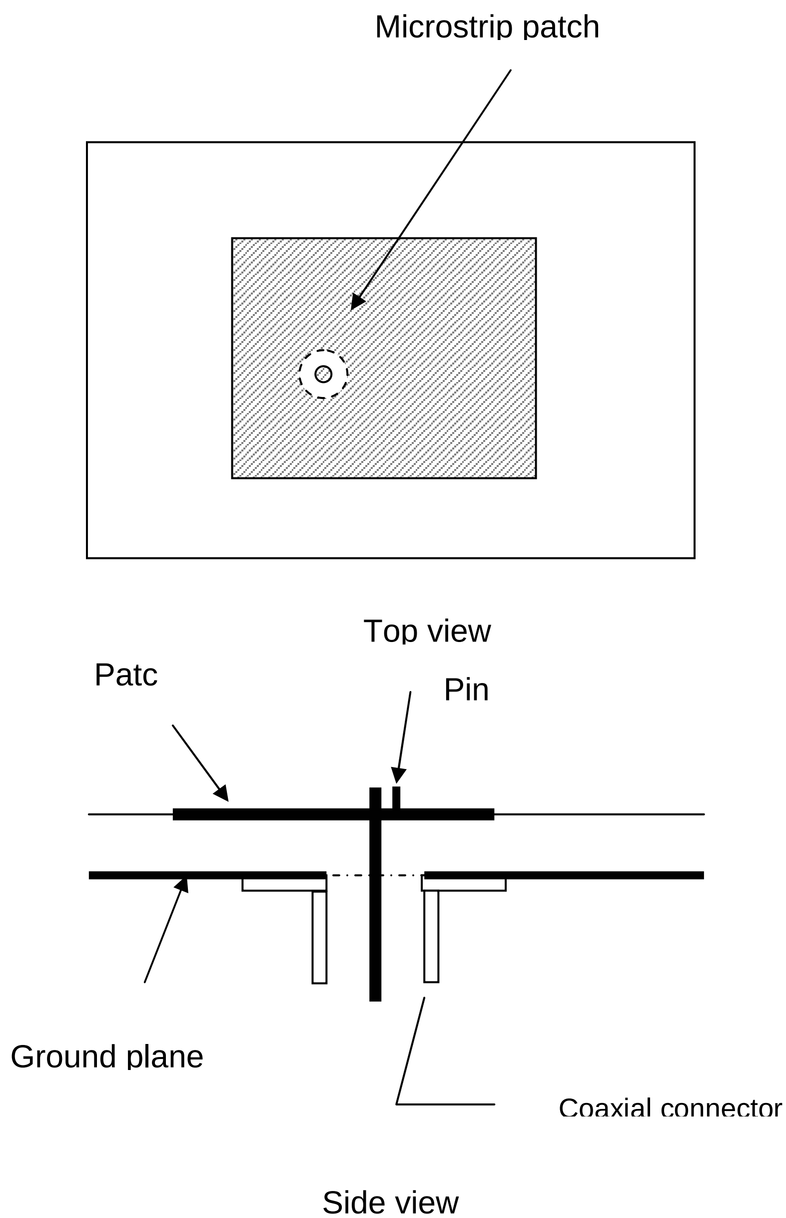


Figure 5.1 Rectangular Micro strip antenna with Co-axial Feed

Following is a brief on the design for chosen configuration.

Configuration of rectangular microstrip antenna with co-axial feed is shown in Fig 5.1. The design procedure given in is followed. The width, 'W' and the length, L of the patch can be calculated in the following way.

5.2.1 ELEMENT WIDTH

The first design step is to choose a suitable dielectric substrate of appropriate thickness. The three most common substrate materials used are rexolite (ε_r=2.6), duroid (ε_r=2.32) and alumina (ε_r=9.8);

For a dielectric substrate of thickness h, an antenna operating frequency of f_r, and for an efficient radiator, a practical width is:

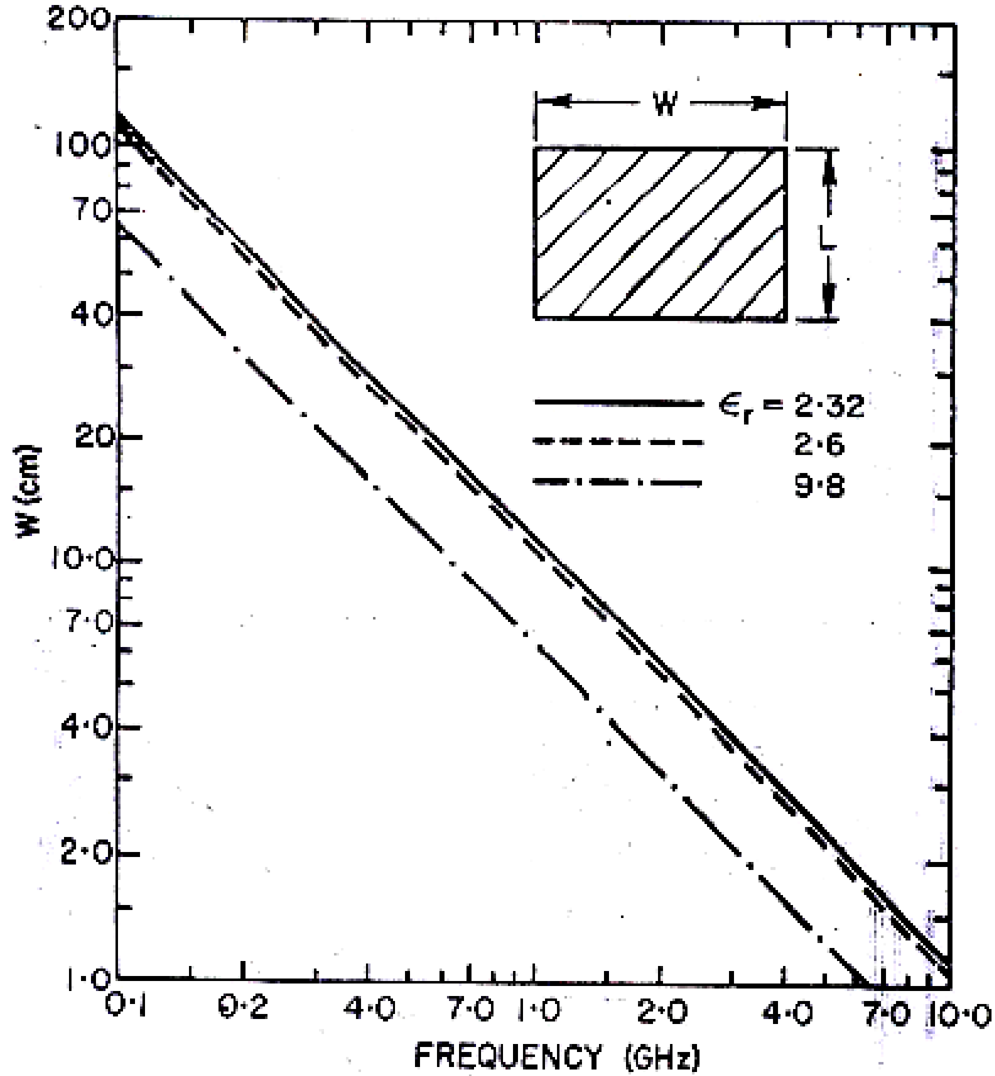
$$W = \frac{c}{2f_r}\left(\frac{\varepsilon_r + 1}{2}\right)^{-1/2} \qquad (5.1)$$

Where c is the velocity of light.

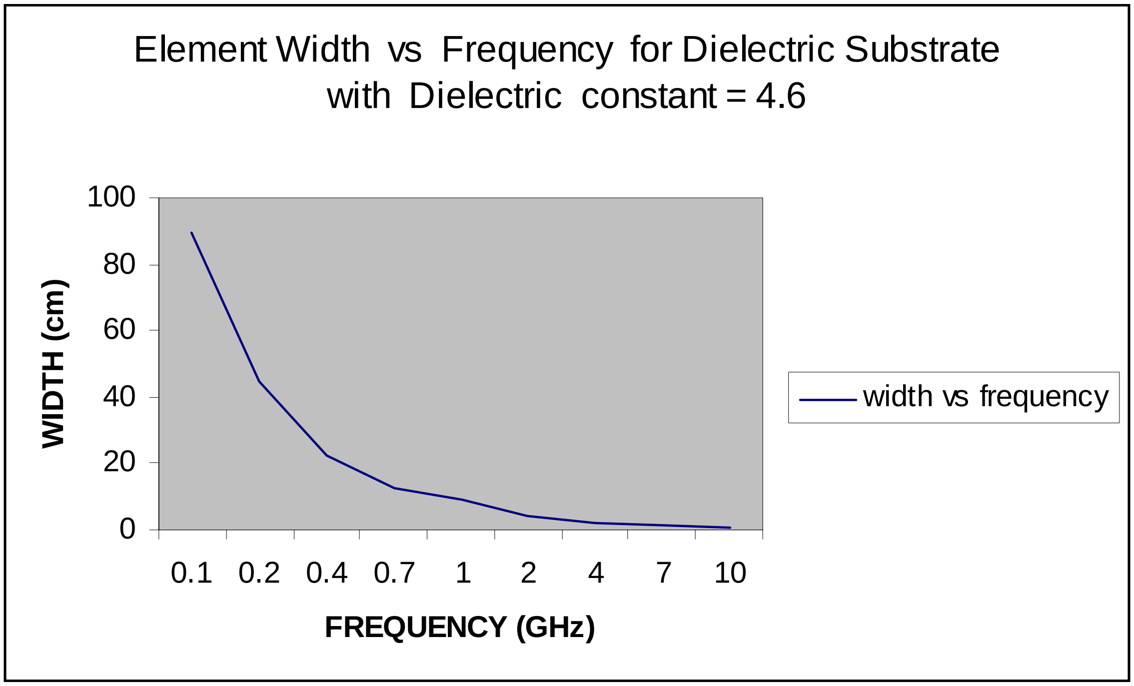
f_r is the resonant frequency

ε_r is the relative Dielectric constant

Of course, other widths may be chosen, But for widths smaller than those selected according to Equation (5.1), radiator efficiency is lower while for larger Widths, the efficiency are greater, but higher order modes may result, causing field distortion. As a design aid, equation (5.1) is plotted in Figure 5.2a for the common dielectric substrates. If other materials are employed equation (5.1) should be used with the appropriate value of ε_r. In this work we have taken substrate of Dielectric constant ε_r =4.6 and width for various frequency ranges plotted in Figure 5.2 a and 5.2b.


W
L
$\epsilon_r = 2.32$
2·6
9·8
W (cm)
200
100
70
40
20
10·0
7·0
4·0
2·0
1·0
0·1
0·2
4·0
7·0
1·0
2·0
4·0
7·0
10·0
FREQUENCY (GHz)

(a)



(b)

Figure 5.2 Element Width vs. Frequency for Different Dielectric Substrates.

5.2.2 Element Length

Once W is known, the next step is the calculation of length which involves several other computations, the first being the effective dielectric constant. Consider the following figure 5.3. The effective dielectric constant is defined as the dielectric constant of the uniform dielectric material so that the patch of the figure 5.3 has identical electrical characteristics, particularly propagation constant, as the actual patch of figure 5.2. For most applications where the dielectric constant of the substrate is much greater than unity, the effective value of ε_e will be closer to the value of actual dielectric constant ε_r of the substrate. The effective dielectric constant is also a function of frequency. As the frequency of operation increases the effective dielectric constant approaches the value of dielectric constant of the substrate is given by:

$$\varepsilon_e = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{12h}{W}\right)^{-1/2} \tag{5.2}$$

Where h is the thickness of the substrate

Because of the fringing effects, electrically the micro strip antenna looks larger than its actual physical dimensions. For the principal E plane (xy-plane), this is demonstrated in figure 2.2c where the dimensions of the patch along its length have been extended on each end by a distance Δl, which is a function of the effective dielectric constant and the width-to-height ratio (W/h).

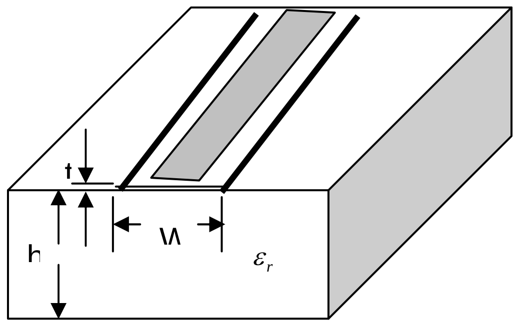


Figure 5.3 Micro strip Line

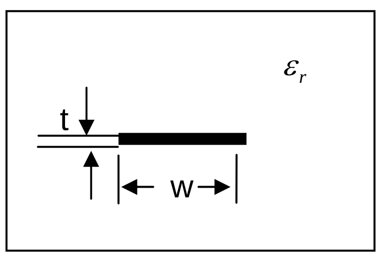


Figure 5.4 Effective Dielectric constant

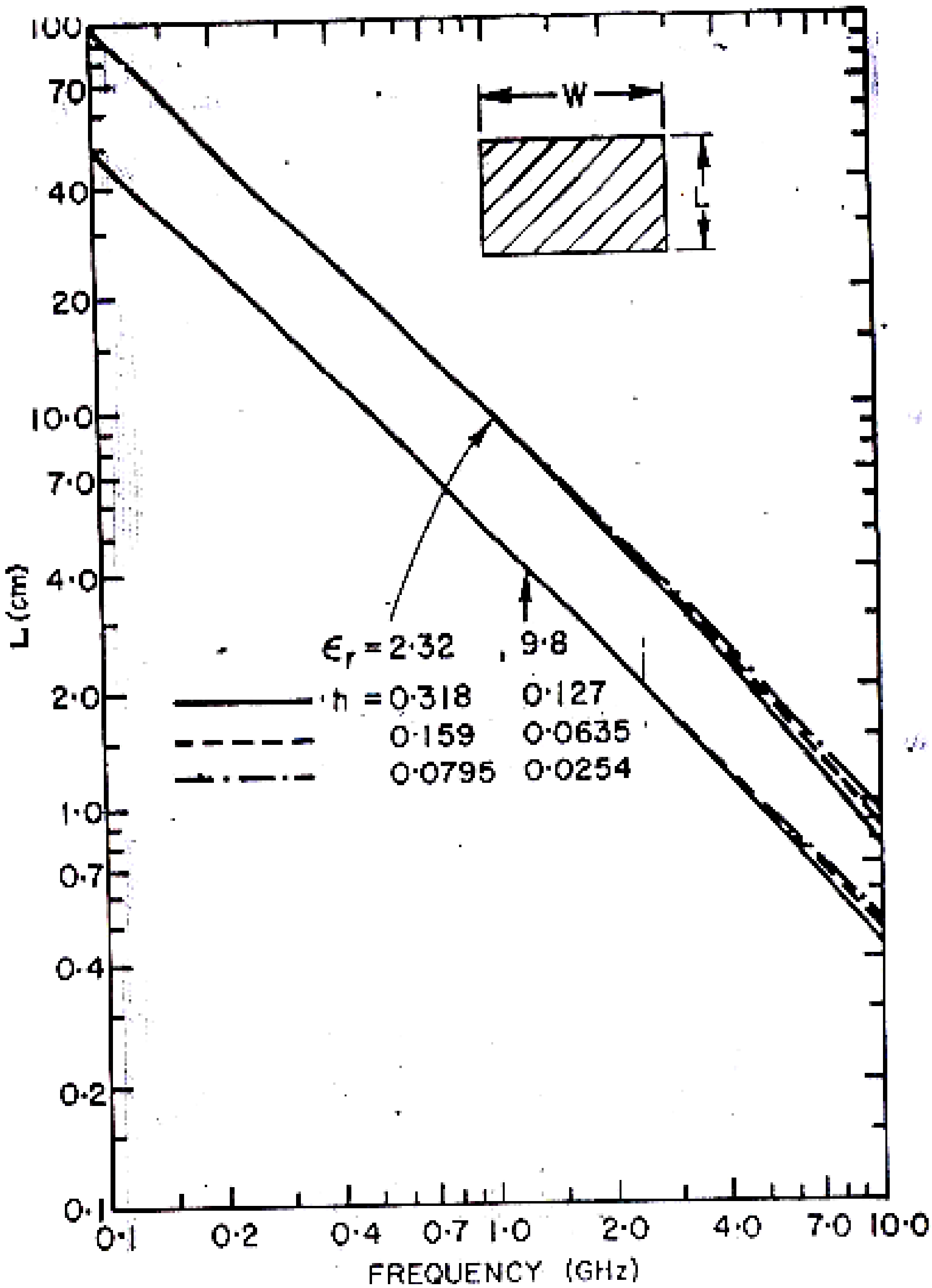
A practical approximate relation for the normalized extension of the length is given by

$$\frac{\Delta l}{h} = 0.412 \frac{(\varepsilon_e + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_e - 0.258)\left(\frac{W}{h} + 0.8\right)} \tag{5.3}$$

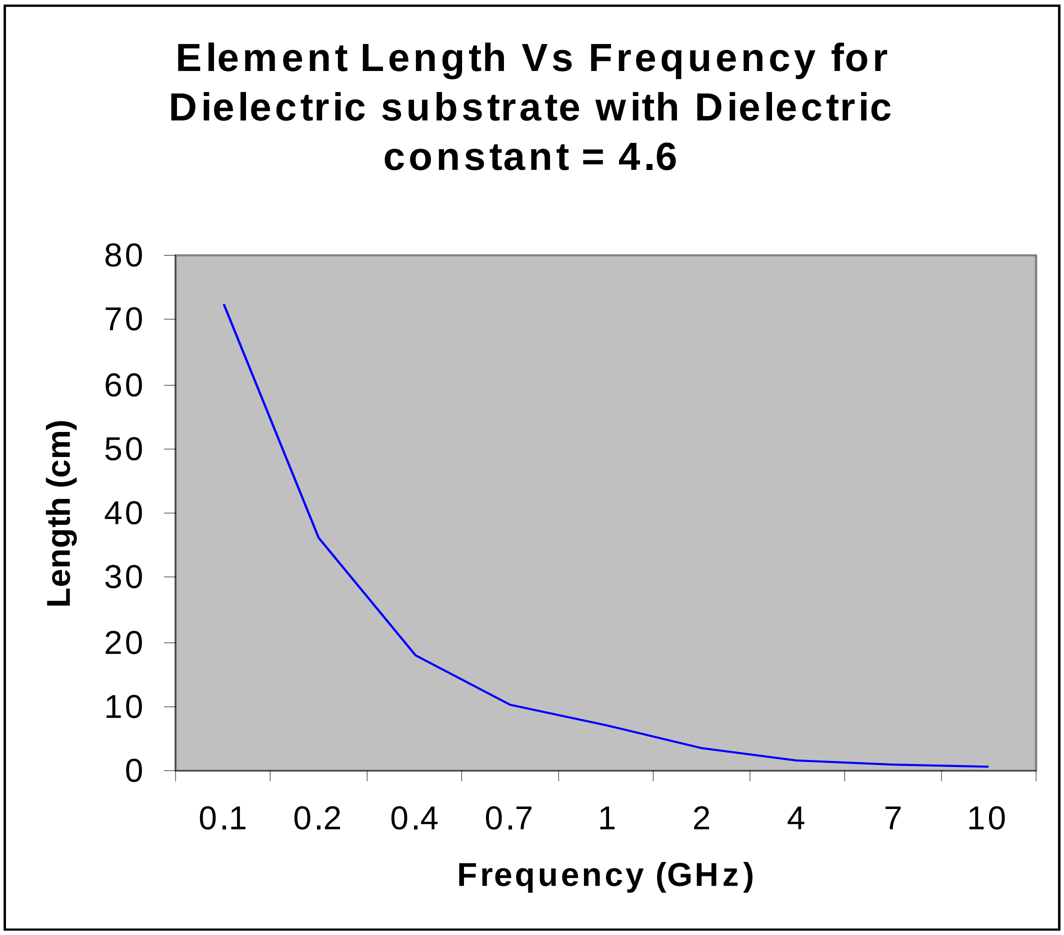
The length of the resonant element is then obtained from the following equation:

$$L = \frac{c}{2 f_r \sqrt{\varepsilon_e}} - 2\Delta l \tag{5.4}$$

Because of the inherent narrow bandwidth of the resonant element, length is a critical parameter, and the above equation should be used to obtain an accurate value for the patch length L. Fig 5.5 which is a plot of L versus f_r for the various substrates and for chosen substrate may then be used to verify the design. Note that for frequencies below 2GHz, the variation in L with h is almost negligible



(a)



(b)

Fig 5.5 Element length vs Frequency for Different Dielectric Substrates

5.3 FABRICATION AND PERFORMANCE OF MICROSTRIP ANTENNAS

5.3.1 Fabrication Procedure

Low antenna bandwidths dictate that dimensional tolerances in micro strip antenna fabrication are critical. Hence considerable care is required in the fabrication process. The typical steps involved in the fabrication of a micro strip antenna can be figured as follows:

The first step involved in the fabrication process is to generate the artwork from drawings. It is then cut according to the dimensions using a precision cutting blade of a manually operated coordinagraph. Accuracy is vital at this stage and depending on the complexity and dimensions of the antenna, either full or enlarged scale artwork should be prepared on a film. The enlarged artwork should be photo reduced using a high precision camera to produce a high resolution negative, which is later used for exposing the photo resist

The laminate should be cleaned to ensure proper adhesion of the photo resist and the necessary resolution in the photo development process. The photo resist is now applied to both sides of the laminate using a laminator. Laminating a metal foil to a dielectric substrate often involves increasing temperature so the laminate is allowed to cool to room temperature prior to exposure and development.

The photographic negative must now be held in every close contact with the polyethylene cover sheet of the applied photo resist using a vacuum frame copy board or other technique, to assure the fine-line resolution required. With exposure to proper wavelength light, a polymerization of the exposed photo resist occurs, making it insoluble in the developer solution. The backside of the antenna is exposed completely without a mask, since the copper foil is retained to act as a ground plane. The protective polyethylene cover sheet of the photo resist is removed and the antenna is now developed in a developer, which removes the soluble photo resist material. Visual inspection is used to assure proper development.

DESIGN

MASTER DRAWING

ART WORK LAY OUT

PHOTO REDUCTION

NAGATIVE DEVELOPMENT

LAMINATE CLEANING

RESIST APPLICATION

RESIST EXPOSURE

RESIST DEVELOPMENT

INSPECTION

ETCHING

BONDING

FINISHING

The next step is etching, which is critical and requires considerable care. After etching, the process photo resist is removed using a stripping solution. Visual and optical inspections are carried out to ensure a good product. If desired a thermal cover bonding may be applied. The edges are smoothened and the antenna is rinsed in water and dried.

The above procedure is the one that is usually followed to develop commercial micro strip antennas. The procedure followed during the project to develop the antenna is quick fabrication process, due to the time constraint. A single clad FRP dielectric substrate is used, which is cut into a square of size λ_o. Self-adhesive copper sheet is used for the patch, which is cut to dimensions. The patch is then pasted on the laminate.
Then using a drill bit a hole for the coaxial feed is located. A connector is then soldered to the back of the antenna. Thus the antenna is fabricated and is ready for testing.

5.3.2 Radiation and Electrical Parameters

Network Analyzer has been used to measure the return loss, VSWR, and impedance. Radiation patterns of the antennas at the design frequency shown in figures (5.4) and(5.5). The bandwidth mainly depends on thickness of the substrate for a givedielectric

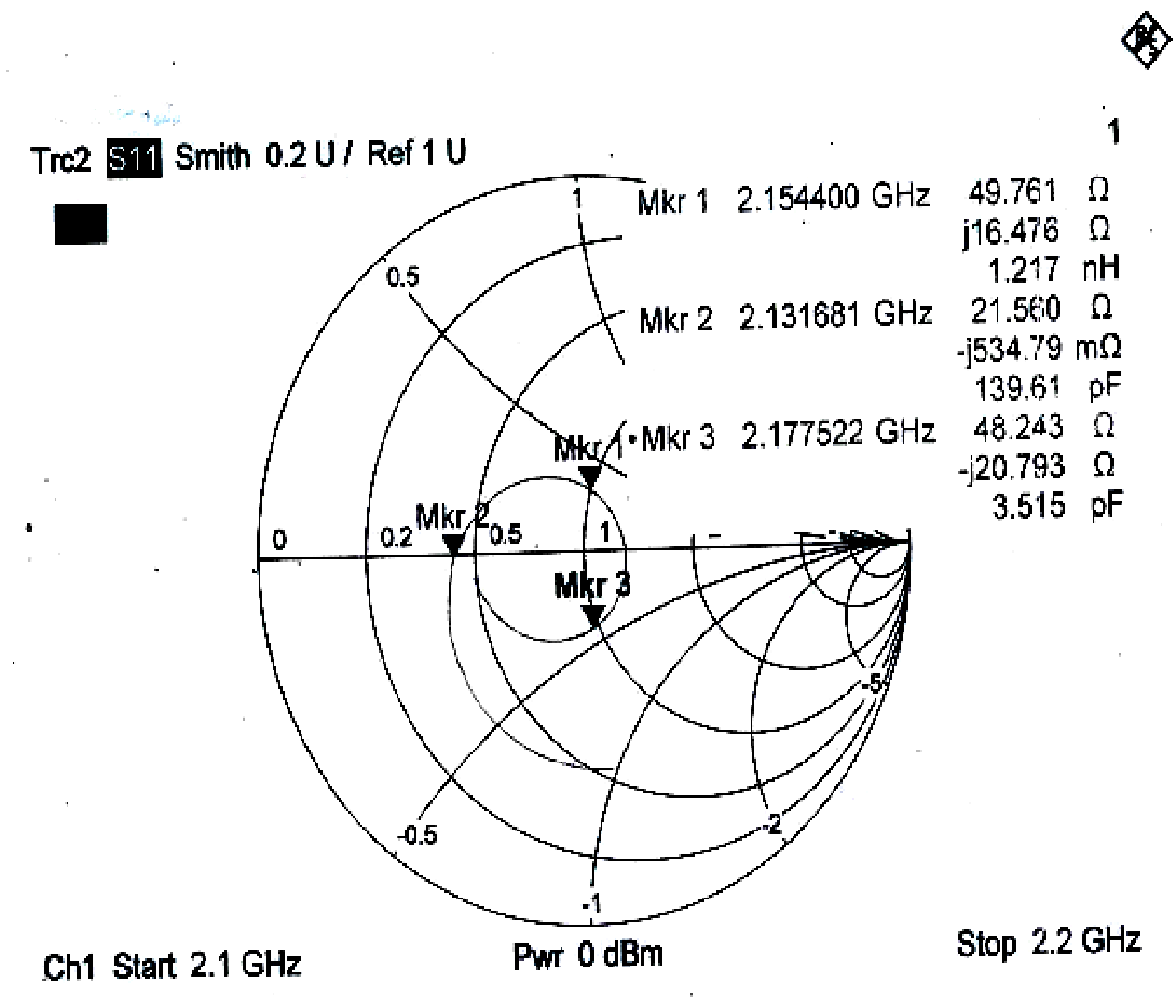


Fig 5.6 Input Impedance Measurement

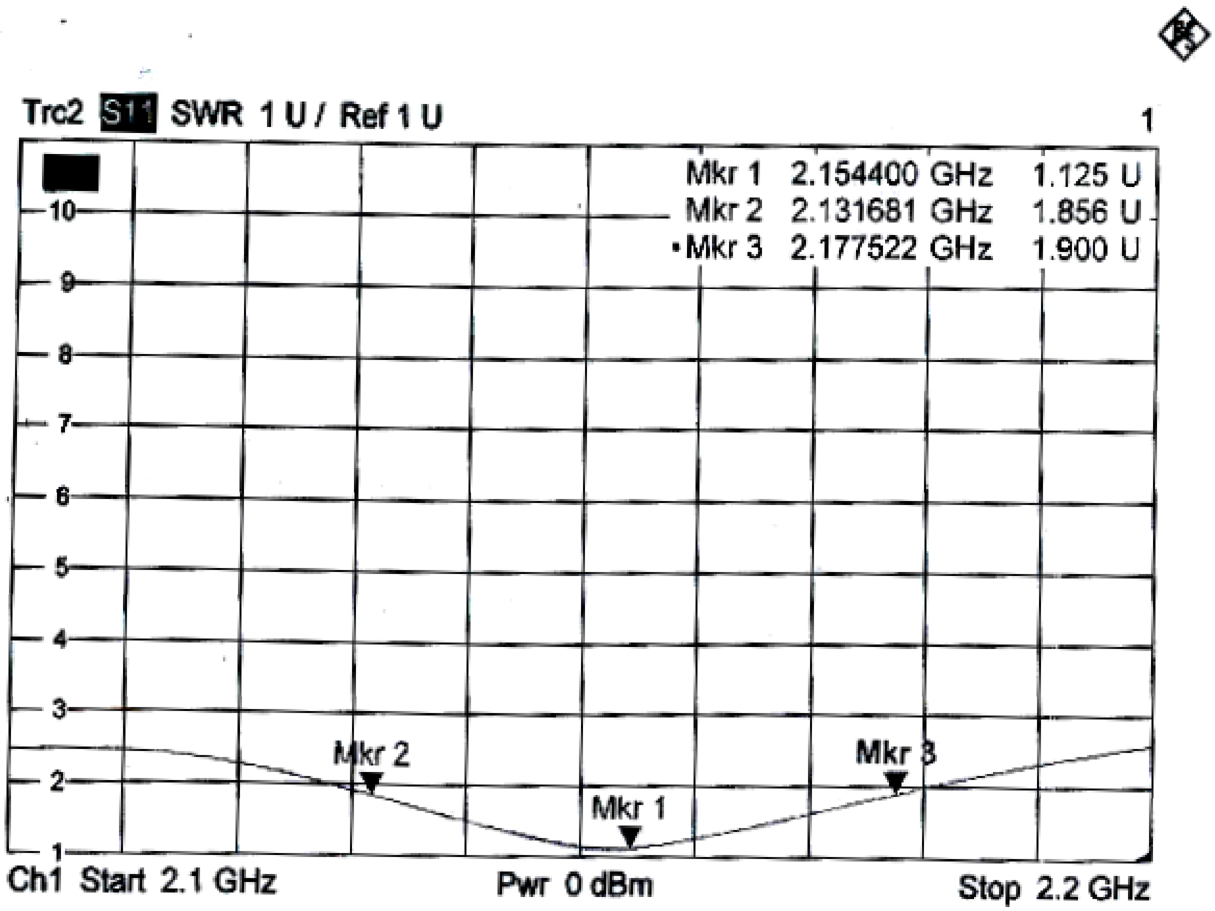


Figure 5.7 Plot of SWR Measurement for Resonant Frequency

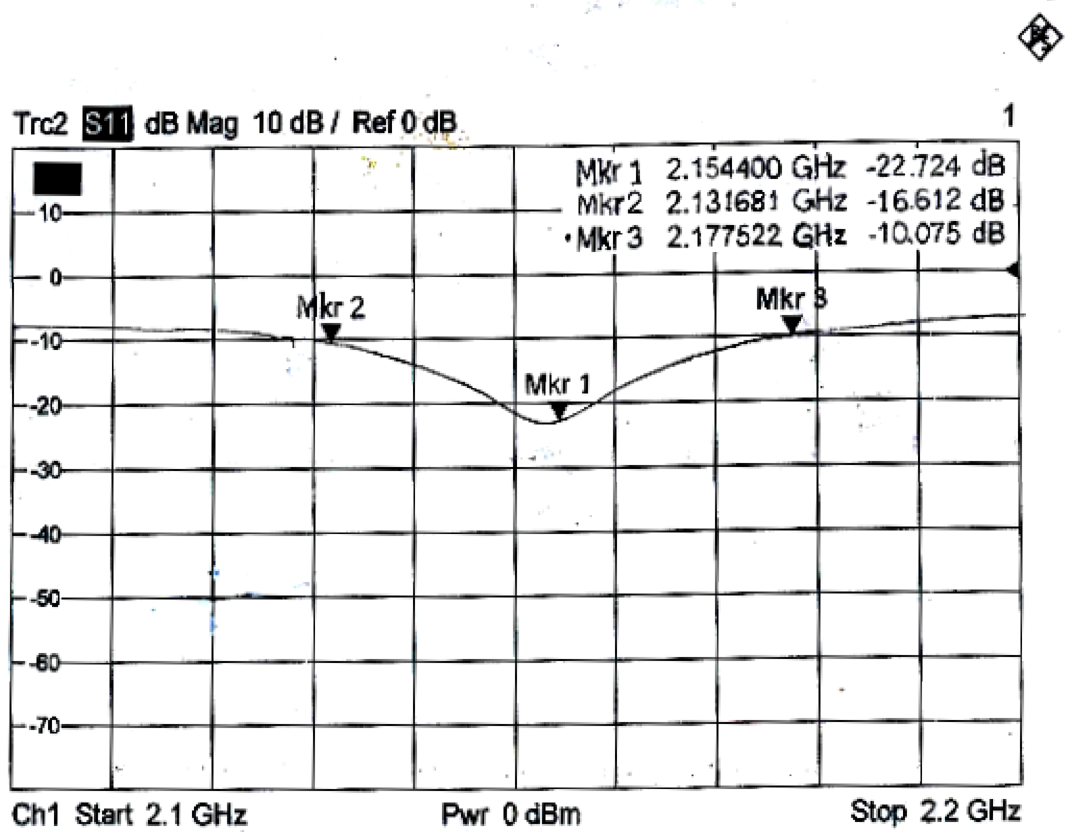


Figure 5.8 Plot of Return Loss Measurement for Resonant frequency

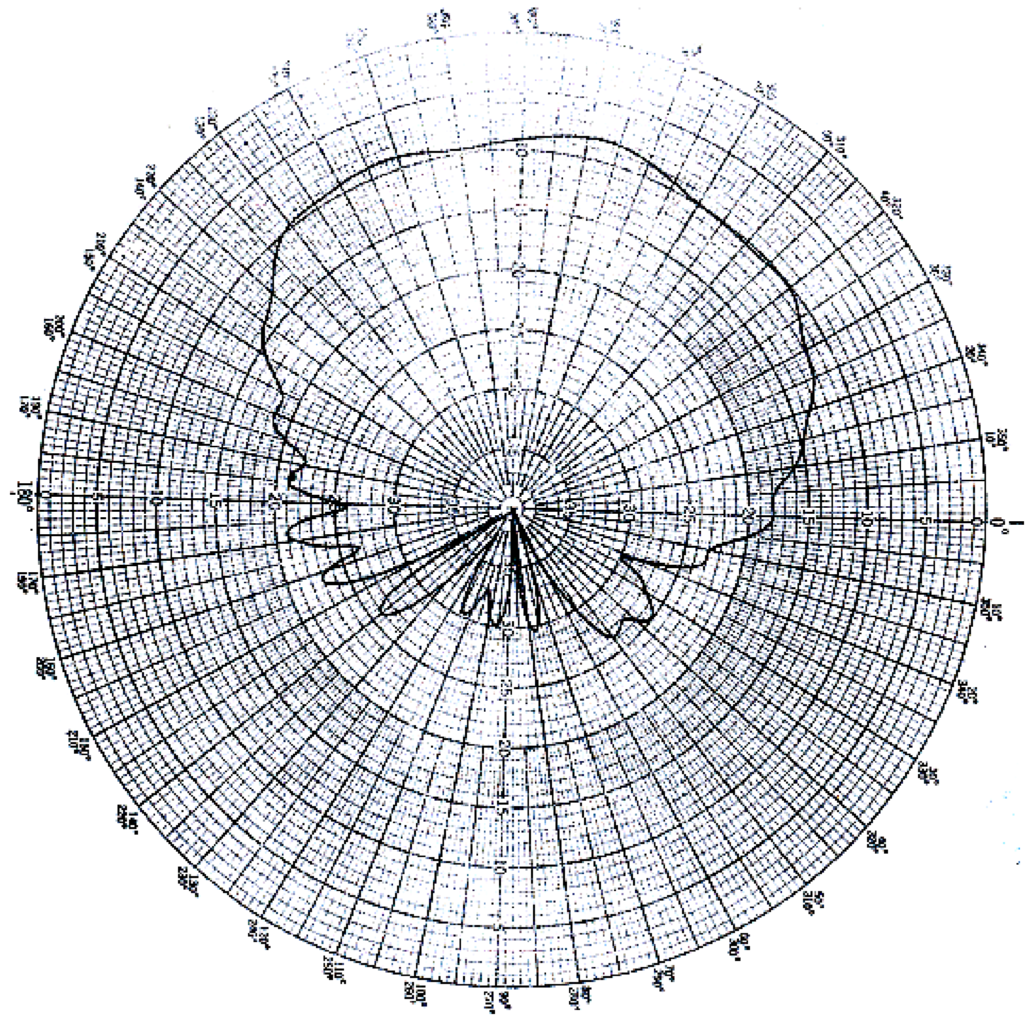


Figure 5.9 *Radiation Pattern of Rectangular Patch on 1.5 mm thin RT/duroid5870 Dielectric (Horizontal Plane)*

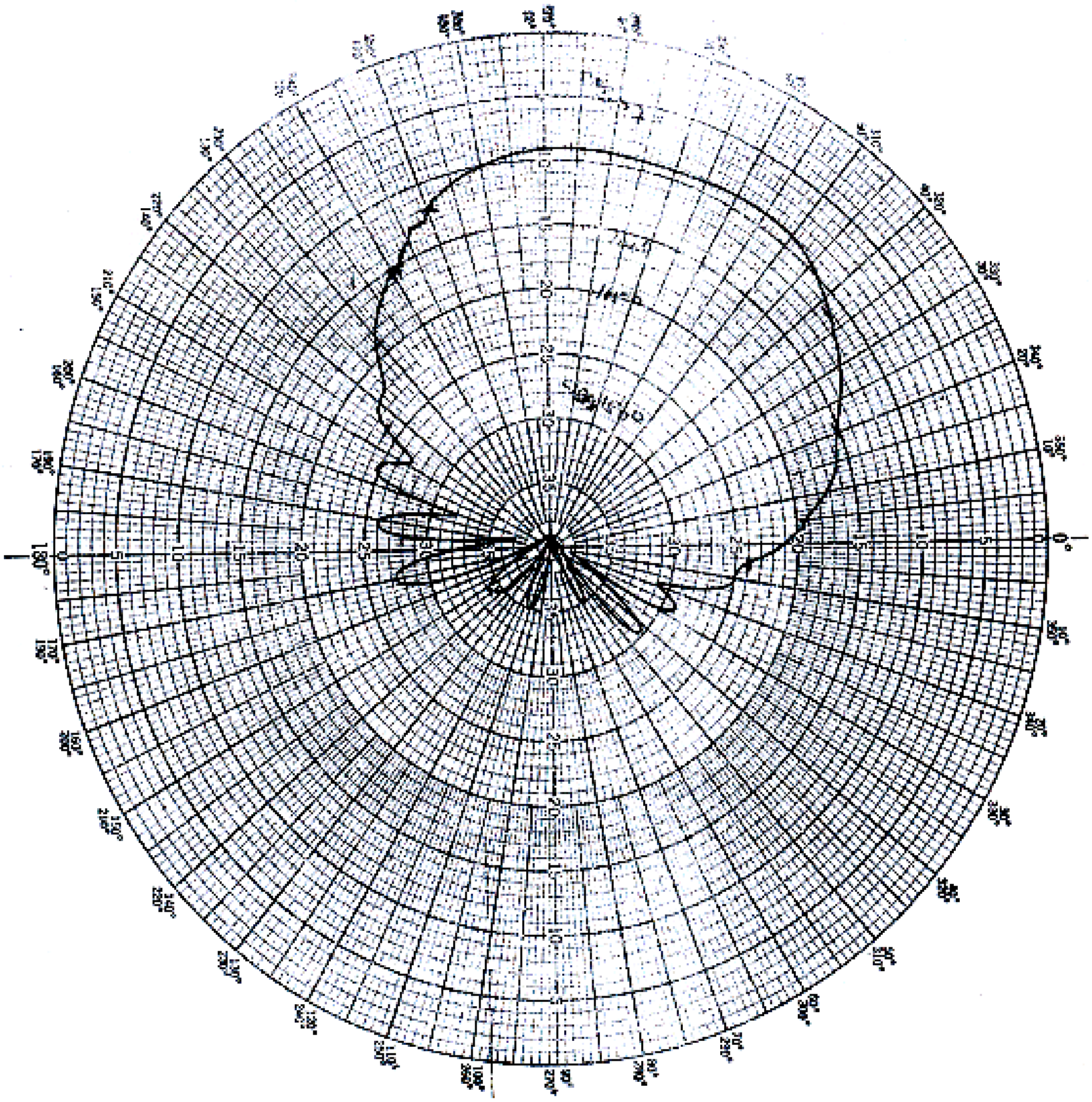


Figure 5.10 Radiation Pattern of Rectangular Patch on 1.5 mm thin RT/Duriod Dielectric (Vertical Plane)

5.4 ANTENNA TESTING

Here is a description of some basic methods, which are used to test the various microstrip antenna parameters.

Impedance measurements

Network Analyser

Input Impedance characteristics

Smith Chart plot analysis

SWR analysis

s12, s21 transmission characteristics

Radiation measurements

Preferably done in an anechoic chamber, Can use a simple set up with the following equipment:

Signal generator (transmitter)

Spectrum analyser (receiver)

Set up which will rotate the antenna 360^o.

Alternatively use a network analyser and connect the transmitting antenna to one port (s11) and receiving antenna to the output port (s22). By moving the antenna at different angles and taking power measurements using the receiver (spectrum analyser or network analyser), a plot of the radiation pattern can be obtained. Cross-polarization measurements can be made by changing the field plane of the receiving antenna.

5.5 TESTING USING THE NETWORK ANALYZER, 8720D

Testing of the antenna is done using an 8720D Two-port Vector Network Analyzer. A network analyzer provides simpled and complete vector network measurements in a compact, fully integrated RF network. 8720D vector network analyzer offers built-in source, receiver and s- parameter test set covering frequencies from 50MHz to 20GHz. With its built- in 3.5-inch disk and serial or parallel ports, it offers good data handling, in addition to higher accuracy and faster sweep speed. It is a compact, economical and easy to use device, which provides accurate and fast tests of microwave filters, amplifiers, mixers, multiple devices and cables in coaxial and non-coaxial environments.

SPECIFICATIONS:

Minimum frequency	50MHz
Maximum Frequency	20GHz
Frequency Resolution	1Hz
Maximum Source Power	+5dBm
Minimum source power	-70dBm
Power Resolution	0.01dB
System Dynamic Range (>2 GHz)	100dB
Test Port Connector	3.5mm

Chapter 6

SIMULATING THE MICROSTRIP ANTENNA USING IE3D SOFTWARE

SIMULATING THE MICROSTRIP ANTENNA USING IE3D SOFTEARE

6.1 INTRODUCTION

Electromagnetic simulation is a new technology to yield high accuracy analysis and design of complicated microwave and RF printed circuit antennas, high speed digital circuits and other electronic components.

IE3D is an integral equation, method-of-moment, full-wave electromagnetic simulator solving current distribution on 3D metallic structures in multi layered dielectric environment. It includes layout editor, electromagnetic simulator, schematic editor and circuit simulator, near field calculation program, format convertor, current and field display program. The IE3D employs a 3D non-uniform triangular and rectangular mixed meshing scheme. It solves the current distribution, slot-field distribution, network s-parameters, radiation patterns and near field on an arbitrarily shaped and oriented 3D metallic structure in a multi-layered dielectric environment. It solves the Maxwell's equations in the integral form and its solutions include the wave effects, discontinuity effects, coupling effects and radiation effects. The simulation results include s-, y-, z-parameters, VSWR, RLC equivalent circuits, current distribution, near field, radiation patterns, directivity, efficiency and gain.

6.2 IE3D SIMULATION CAPABILITIES

IE3D is an integrated electromagnetic simulation and optimization package for the analysis and design of microwave circuits, microwave and millimeter wave integrated circuits (MMIC), RF printed circuits, HTS circuits and filters, microstrip patch antennas, strip lines, coaxial lines, rectangular waveguides, 3D interconnects, conical and cylindrical helix antennas, inverted antennas. Wire antennas, various kinds of wireless antennas, IC transmission lines, IC packaging, electromagnetic applications in medical sciences.

6.3 IE3D FEATURES

1. Modeling true 3D metallic structures in layered dielectric environments.
2. High efficiency, high accuracy and low cost electromagnetic simulation tools on PCs with Windows based graphic interface.
3. The MS Windows based menu driven graphic interface allows interactive construction of 3D and multi-layered metallic structures as a set of polygons.
4. A built-in library enables the construction of complicated structures such as circles, rings, spheres, rectangular and circular spirals, cylindrical and conical vias and helices.
5. Automatic non-uniform mesh generator with rectangular and triangular cells.
6. Flexible de-embedding of circuit parameters.
7. Modeling structures with finite ground planes and differential feed structures.
8. Accurate modeling of true 3D metallic structures and metal thickness.
9. Electromagnetic optimization.
10. Modeling of thin, lossy and high dielectric constant substrates.
11. Mixed electromagnetic and nodal analysis.
12. Efficient matrix solvers.
13. Cartesian & Smith chart display of S, Y, Z parameters, VSWR and radiation patterns.
14. Extracting RLC-equivalent circuits for structures.
15. 3D, 2D display of current distribution, radiation patterns and near field.
16. Magnetic current modeling of slot structures.
17. "Simulate and find Excitation" feature allowing monitoring of array power distribution on network.
18. Flexible utility features and built-in circuit simulator.
19. Adaptive Intelli-Fit scheme provides fast and accurate simulation results for wide bandwidth structures.

6.4 COMPUTER PROGRAMMING IN MATLAB

6.4.1 Merits Of Programming

The design of micro strip antenna involves many lengthy and tedious calculations such as width, length, feed location, dimensions of feed (for strip line feed). As these calculations are cumber some and time consuming when done by hand a computer programming approach is adopted to simplify the task.

6.4.2 Program to Find Width, Length and Feed Point

The width and length of the micro strip antenna are to be calculated from the corresponding equations as given in Chapter 5. The next parameter to be found is the feed location. In the project, the coaxial type of feed is chosen to feed the antenna. The impedance of the feed is 50Ω. As told earlier, a large range of input impedance values can be obtained along the length of the antenna. But for matching the feed to the antenna, the point of feed should be that point where the impedance of the antenna is 50Ω. Hence, in the program, the importance of the antenna is found at every point along the length of the antenna according to the standard formulae given in chapter 5, and the point of feed is hence found.

Thus the program in Matlab is to find the width and length of the micro strip antenna and also the feed location . It takes inputs as frequency of operation (in GHz), substrate thickness (in cm) and dielectric constant.

6.5 SIMULATION

Using this IE3D software, simulation results to estimate the performance of the antenna have been obtained. The plots of VSWR, Smith’s Chart, Radiation pattern in 2D and 3D Polar format, Directivity, Gain and efficiency have been obtained.

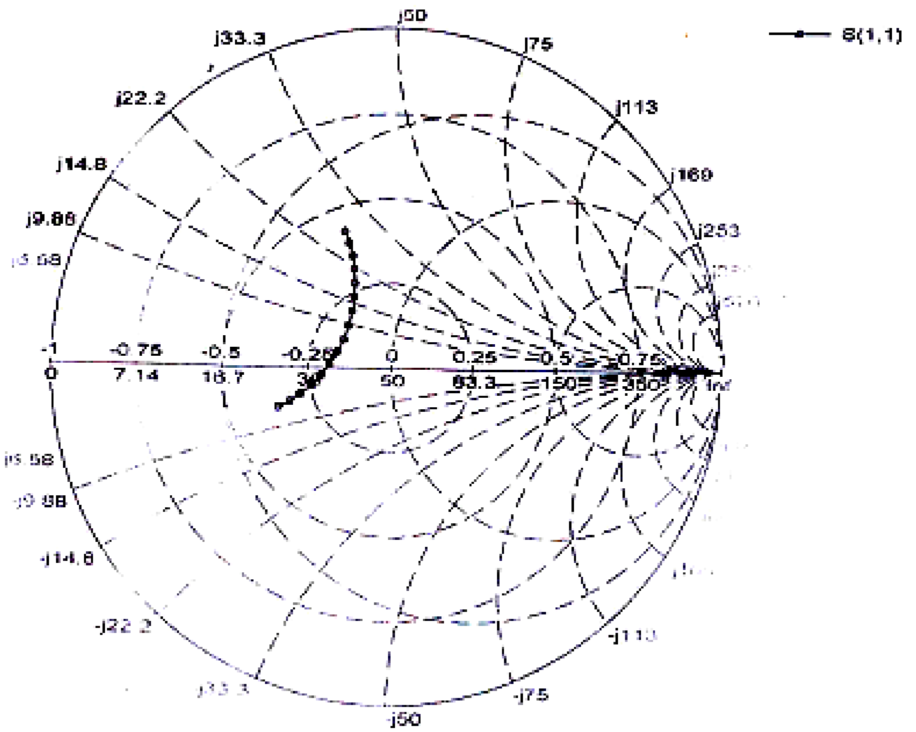


Figure 6.1 Simulated Plot for Input impedance measurement

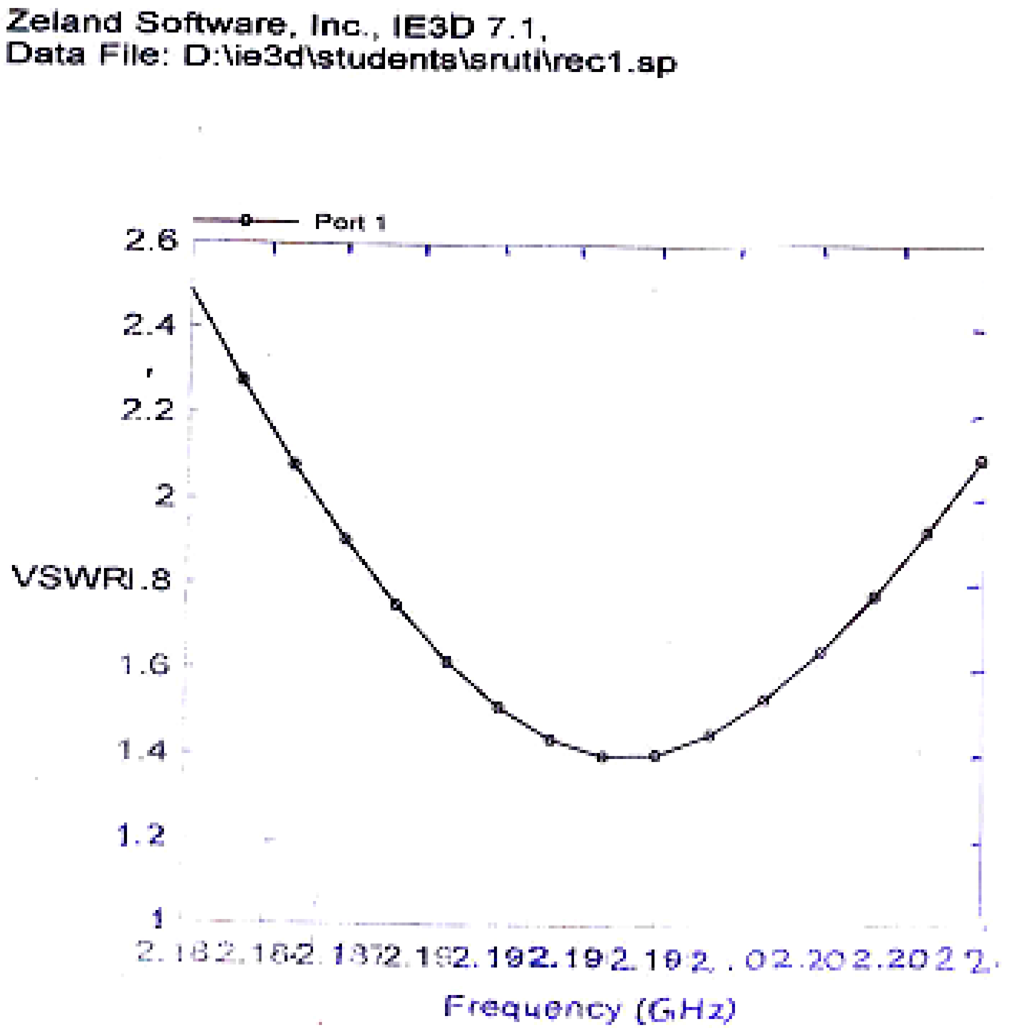
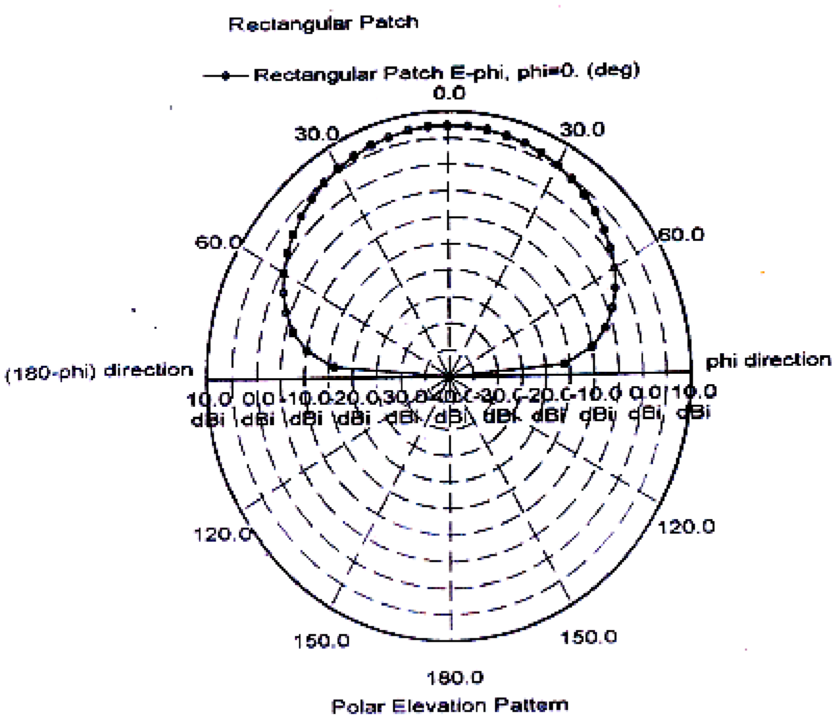
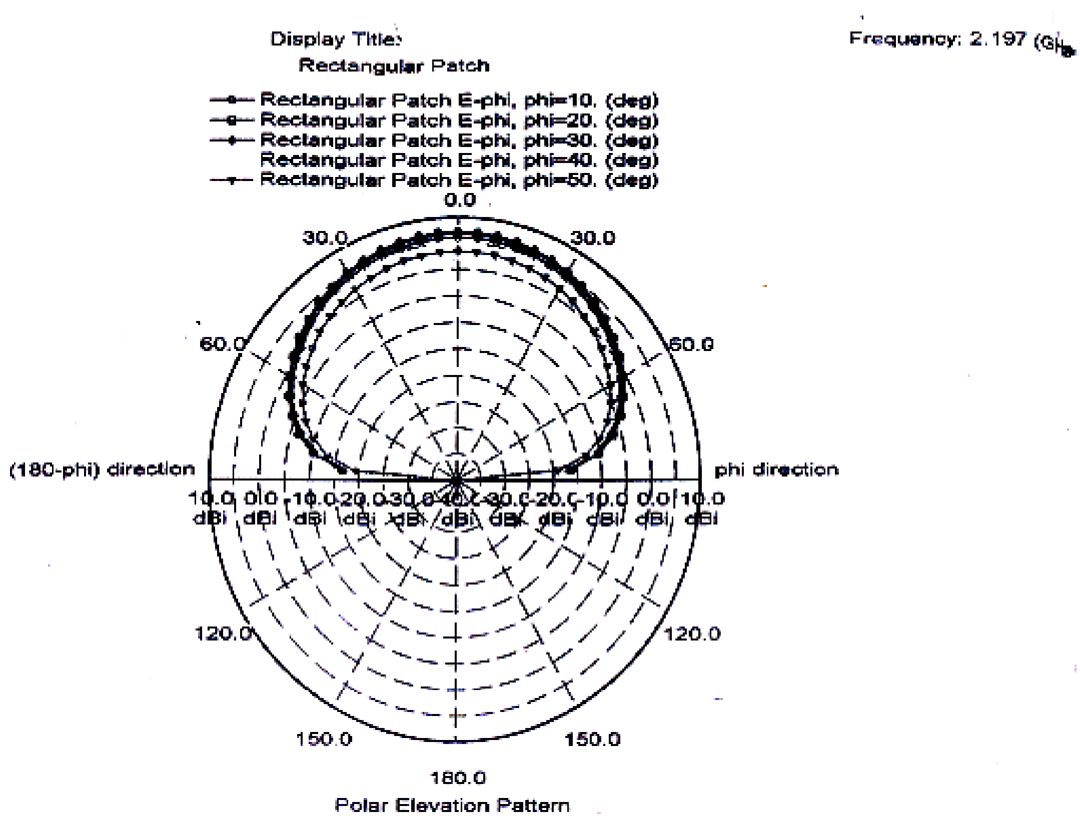
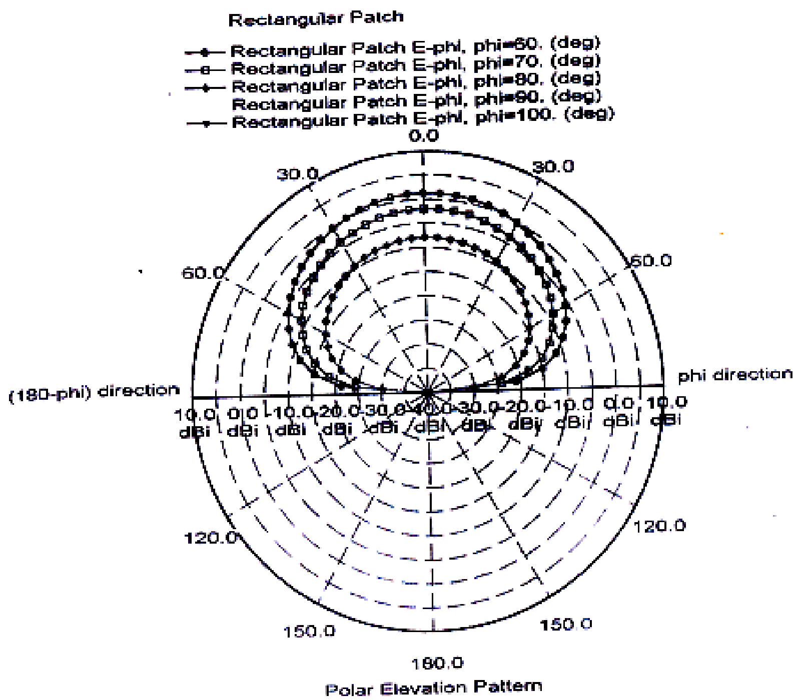


Figure 6.2 Simulated Plot for SWR measurement


Rectangular Patch
Rectangular Patch E-phi, phi=0. (deg)
0.0
30.0
30.0
60.0
60.0
(180-phi) direction
phi direction
120.0
120.0
150.0
150.0
180.0
Polar Elevation Pattern


Display Title:
Rectangular Patch
Frequency: 2.197
Rectangular Patch E-phi, phi=10. (deg)
Rectangular Patch E-phi, phi=20. (deg)
Rectangular Patch E-phi, phi=30. (deg)
Rectangular Patch E-phi, phi=40. (deg)
Rectangular Patch E-phi, phi=50. (deg)
0.0
30.0
30.0
60.0
60.0
(180-phi) direction
phi direction
120.0
120.0
150.0
150.0
180.0
Polar Elevation Pattern



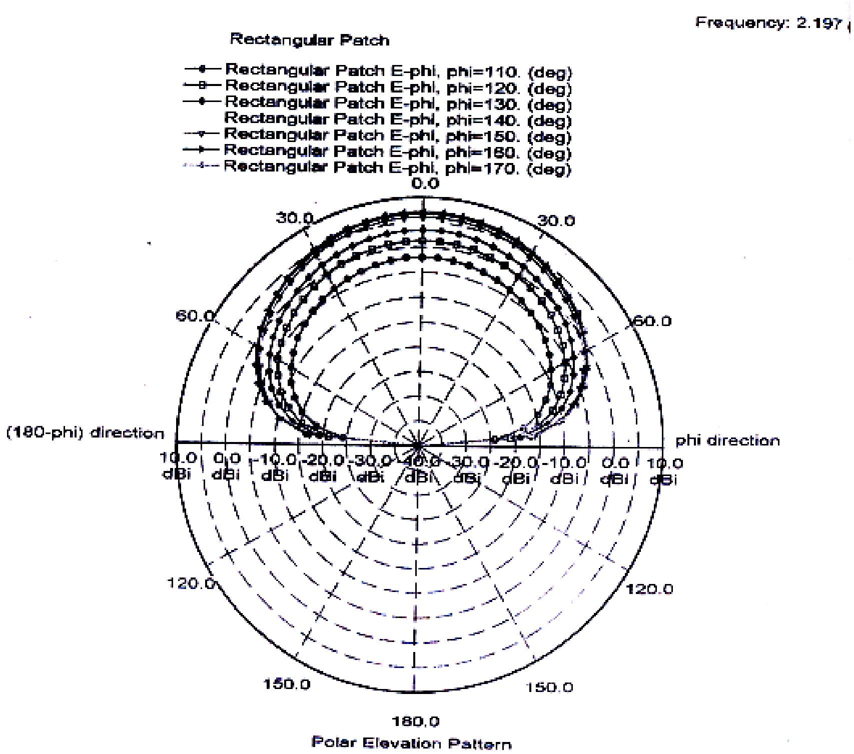


Figure 6.3 Simulated Radiation pattern of Rectangular Microstrip Antenna (VP)

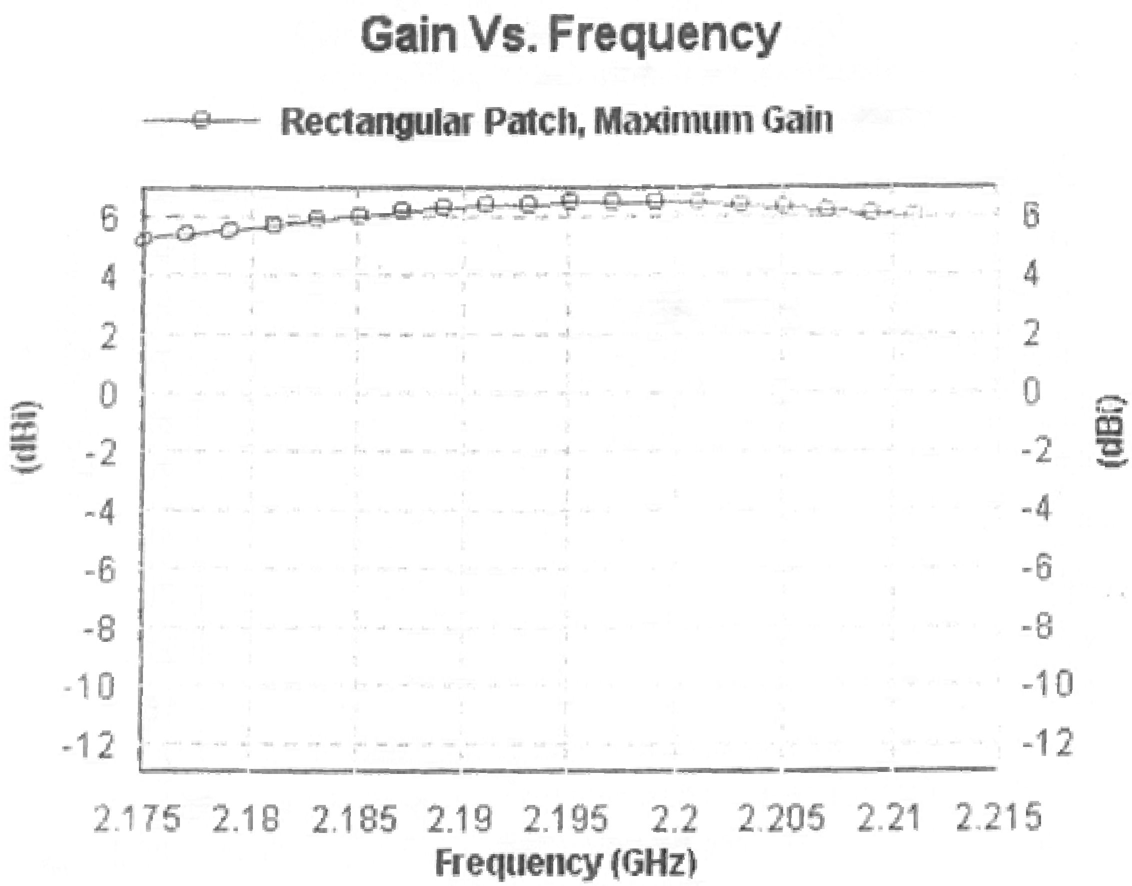


Figure 6.4 Simulated Plot of Gain Vs Frequency

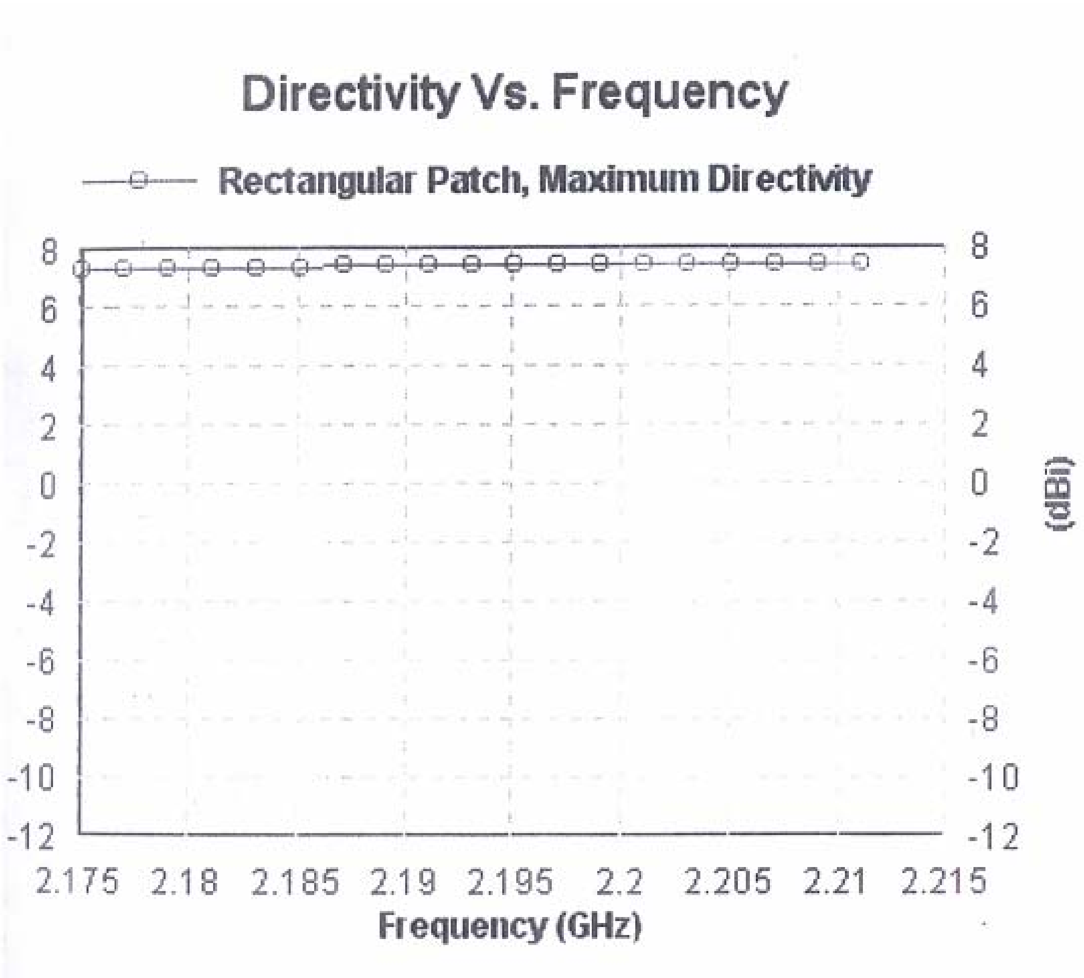


Figure 6.5 Simulated Plot of Directivity Vs Frequency

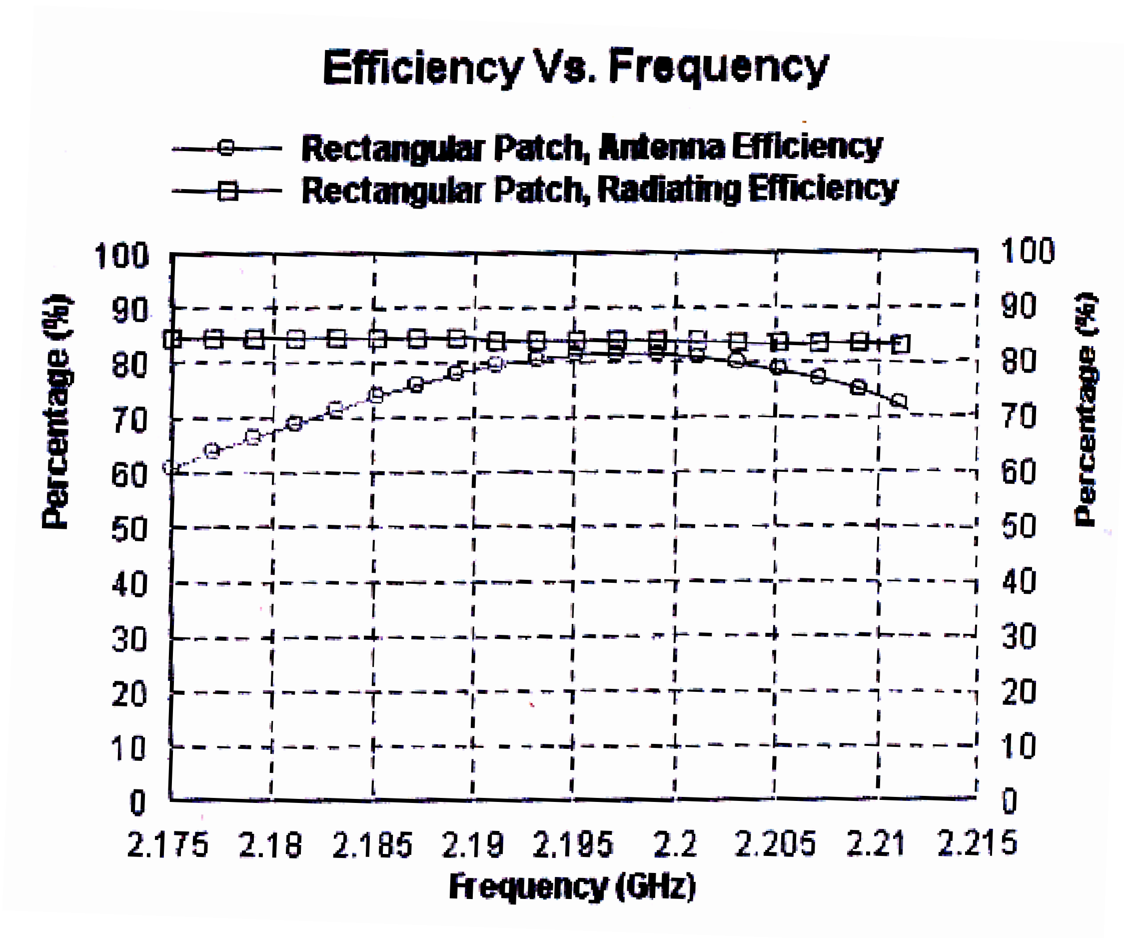


Figure 6.6 Simulated Plot of Efficiency Vs Frequency

Chapter 7

IMPORTANCE OF THE WORK

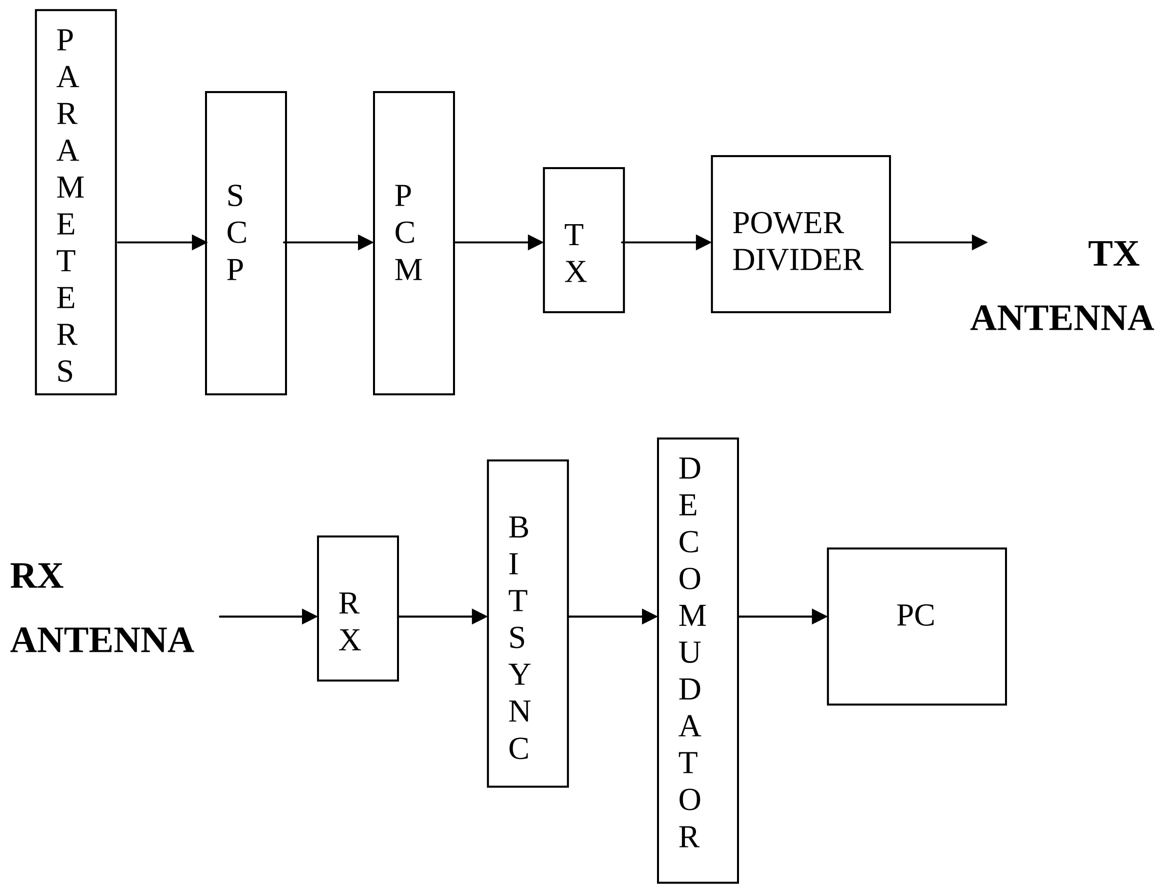
Block Diagram of Telemetry System

Photographs of Realized Antenna

IMPORTANCE OF THE WORK

Design of rectangular patch antenna plays an important role in telemetry systems of an article. Telemetry system used to monitor the parameters an article while in flight trial. This data useful to analyze the performance of the flight. This data also enhances the requirement of technology changes if any required.

7.1 BLOCK DIAGRAM OF TELEMETRY SYSTEM

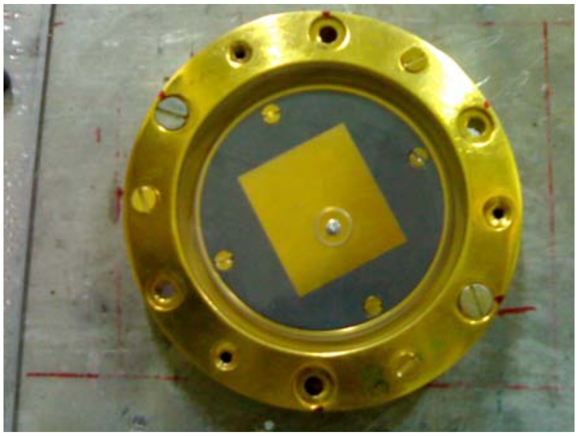


Sensors in the onboard article gives parameters such as temperature, vibrations level in terms of milli voltages. These low voltages are converted to +/- 2.5 v level by means of signal conditioner package. Signal conditioner output is given to pulse code modulator to get digital data. Output of PCM is fed to transmitter and then modulated. The digital modulated signal transmitted in free space by means of rectangular patch antenna.

In the ground station receiving antenna used to capture the signal. The captured signal is given to bit synchronizer and successively to Decomudator. The decomudator output is given to personal computer, where we can analyze the data.

Thus the design of rectangular patch antenna is very important in the telemetry system. Designed rectangular patch antenna is gone through environmental tests like vibration test and thermal cycling etc to prove antenna as flight worthy.

7.2 PHOTOGRAPHS OF REALIZED ANTENNA:



Chapter 8

CONCLUSIONS AND FUTURE SCOPE OF THE WORK

CONCLUSIONS AND FUTURE SCOPE OFWORK

8.1 CONCLUSIONS

A rectangular micro strip antenna is designed using the appropriate design formulae and is fabricated using the quick fabrication procedure and is tested using vector network analyzer, 8720D.The antenna design is worked out at 2250 MHz frequency. Even though the antenna is desired to operate at this frequency, when tested practically it is found that, it is resonating at 2254 MHz.

The dielectric constant (permittivity) plays a major role in the overall performance of a patch antenna. It affects both the width, in turn the characteristic impedance and the length resulting in an altered resonant frequency. We have used the Duriod substrate , but the permittivity (ε_r) of the substrate alters from batch to batch, sometimes even between different sheets of the substrate.

The Bandwidth of the patch antenna depends largely on the permittivity (ε_r) and thickness of the dielectric substrate. Ideally, a thick dielectric, lower permittivity (ε_r), low insertion loss is preferred for broadband purposes.

From the result I observed that the beam width of a microstrip element can be increased by choosing a smaller element, thus reducing W and L. For given resonant frequency, these dimensions may be changed by selecting a substrate having a higher relative permittivity. The advantages of microstrip antennas are that they are low-cost, conformable, lightweight and low profile, while both linear and circular polarization is easily achieved. These attributes are desirable when considering antennas for RFID Reader systems.

This antenna material is also ideal for Antenna Arrays (two or more radiating elements). Longer ranges, larger areas, faster assembly line speeds will all benefit from the focused energy and directionality available through antenna array beam forming. The print and etch process of printed circuit boards is very repeatable and highly cost effective. It eliminates the labor and technician work required to insure proper phase matching between elements. It also reduces energy requirements of the system. The reduced side lobe emissions reduce false alarms, reduce interference between other antennas and minimize emission in unwanted directions.

8.2 FUTURE SCOPE OF THE WORK

- This antenna can be used as a basic element in an array.
- Try and redesign the antenna by using low loss substrates such as Rogers RT/Duriod material, Taconic TLX substrates etc.
- The work can also be extended to transform the passive antenna to an “Active Aperture Micro strip Antenna. This includes adding an active component to the passive antenna.
- Dual feed MSA configurations yield wider BW and narrower BW as compared to the single feed MSA configurations. When four parasitic patches are placed around the fed patch the BW and gain can be improved.
- Circular polarization is obtained when second feed is placed orthogonal to the first one.
- Design of Array to obtain better directivity .

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[7] **Internal Resources of DRDL**

APPENDIX-I

COMPARISON BETWEEN PRACTICAL AND SIMULATED DATA

ANTENNA SPECIFICATIONS	PRACTICAL	MATLAB/ IE3D
TELEMETRY SPOT FREQUENCY	2.255 GHz	2.255 GHz
BANDWIDTH	18 MHz	20.1/17 MHz
VSWR	1.315	1.5/1.078
HALFPOWER BEAM WIDTH(3db)(E -PLANE)	88°	81.78°/95°
HALFPOWER BEAM WIDTH(3db)(H -PLANE)	90°	123.3°/80°
RETURN LOSS	-17.3	-14/-28.511
GAIN(db)	6.7	6.45/6.46
LENGH(mm)	43	42.86/42.4
WIDTH(mm)	52	51.54/43
FEED LOCATION(mm)	16	15/15
DIELECTRIC MATERIAL	RT/DURIOD	RT/DURIOD
DIELECTRIC CONSTANT	2.33	2.33
THICKNESS OF SUBSTRATE(mm)	1.5748	1.5748/1.5748
POLARISATION	LINEAR	LINEAR